MOBILE BROADBAND

UNIK4230: Mobile Communications

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Mobile Broadband

Materials used from:

1. **Nokia Siemens Networks**
2. **LTE for UMTS**. Evolution to LTE-Advanced. 2nd Edition. Harri Holma and Antti Toskala

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Agenda

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Strong momentum in mobile broadband

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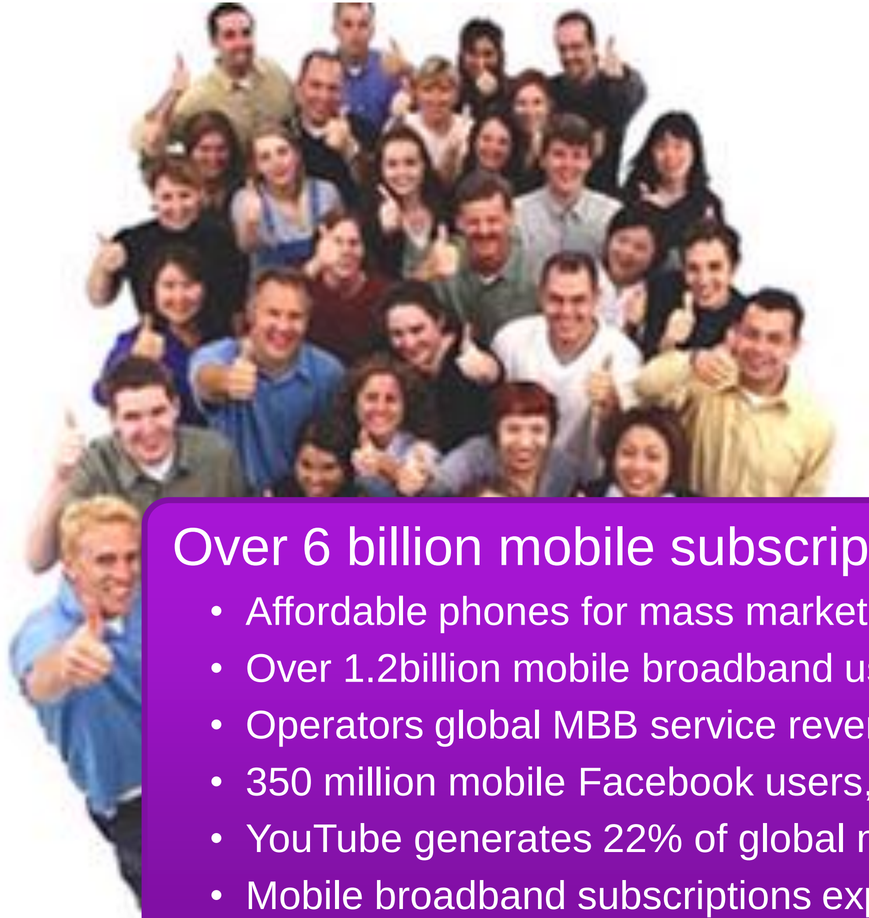
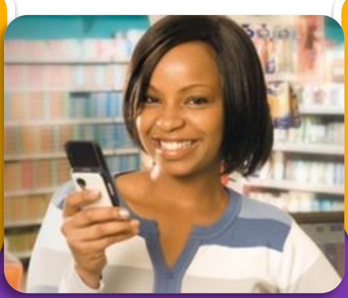


Devices



Affordable & exciting MBB offerings

Services

Networks

Over 6 billion mobile subscriptions

- Affordable phones for mass market
- Over 1.2billion mobile broadband users, 50% y-o-y growth
- Operators global MBB service revenue grow annually 25%
- 350 million mobile Facebook users, out of 800 million total
- YouTube generates 22% of global mobile data traffic
- Mobile broadband subscriptions expected to exceed wireline broadband users within 2 years

Source: NSN BI, Industry analysts

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Mobile broadband traffic more than doubles every year

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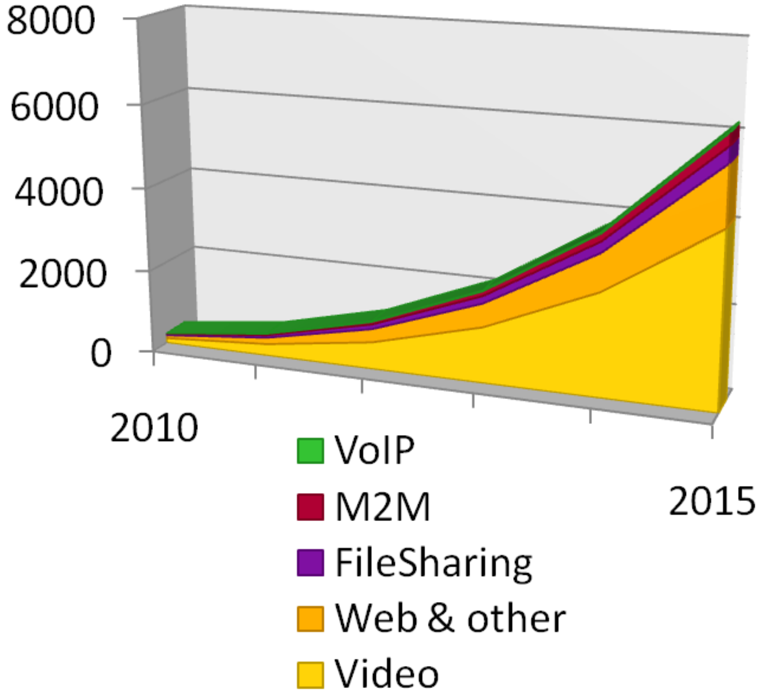
Video traffic has overtaken everything else

Mobile application traffic
Petabytes per month

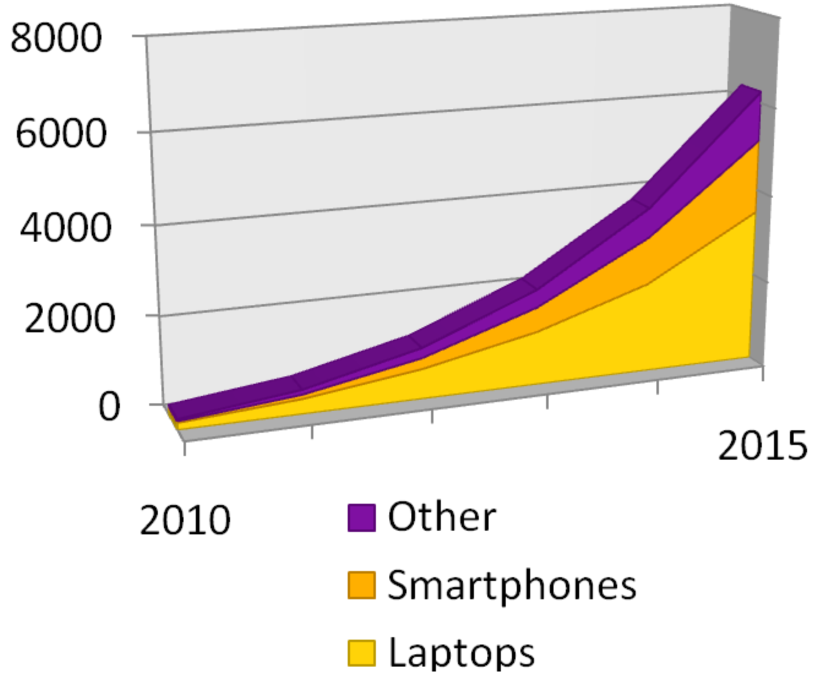


Source: NSN BI, Industry analysts






Mobile data traffic
Petabytes per month



Source: NSN BI, Industry analysts

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Factors impacting MBB/LTE take off & competiveness

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Device portfolio



- Smart phones, low end MBB phones
- Sticks, tablets, laptops, Mi-Fi
- Subsidizing usage of 3G/LTE devices

Content & applications


- Own applications, services from Internet
- Partnering with local brands & device vendors
- Foster country specific killer apps

Attractive bundles

- Voice, data, sms, devices, triple/quad play
- Converged fixed and mobile offering
- Content, email, navigation, security

Network capabilities




- Capacity, coverage, quality
- 6-sector, active antenna, site density, spectrum
- Small cells, offloading, traffic management

Agenda

MOBILE BROADBAND

- Introduction
- **WCDMA/HSPA/HSPA+**
  - **Introduction**
  - HSPA device ecosystem overview
  - HSPA technology and evolution
- LTE
- LTE-Advanced
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UMTS Air Interface technologies

UMTS Air interface is built based on two technological solutions

- WCDMA – FDD
- WCDMA – TDD

WCDMA – FDD is the more widely used solution

- FDD: Separate UL and DL frequency band

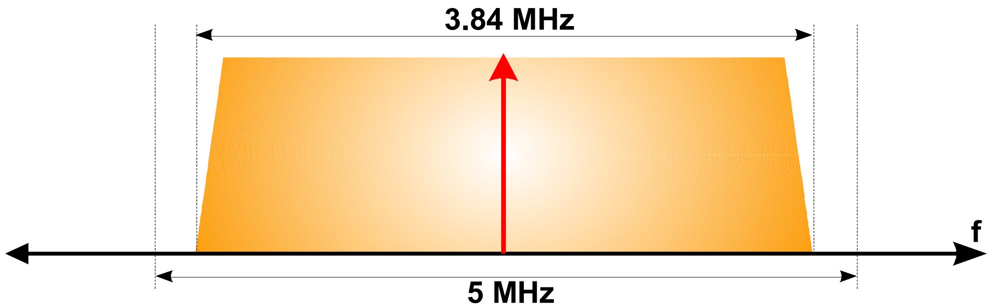
WCDMA – TDD technology is currently used in limited number of networks

- TDD: UL and DL separated by time, utilizing same frequency

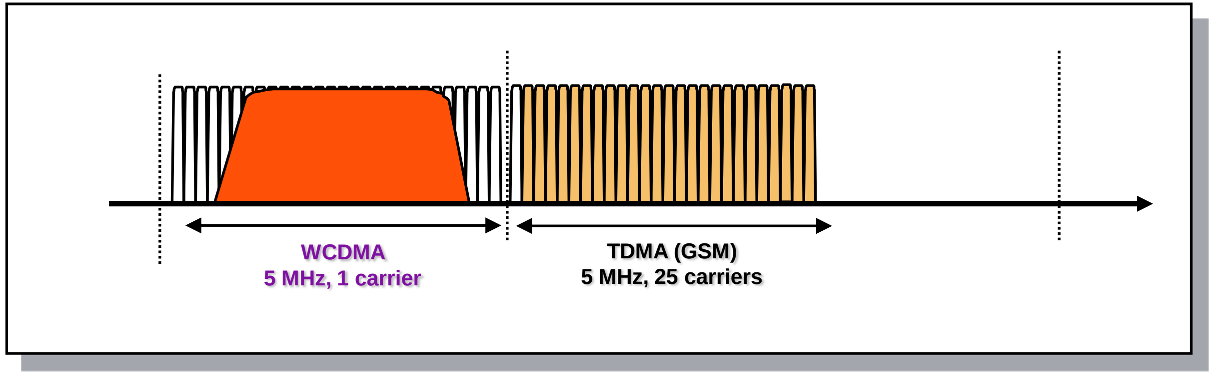
Both technologies have own dedicated frequency bands

WCDMA Technology

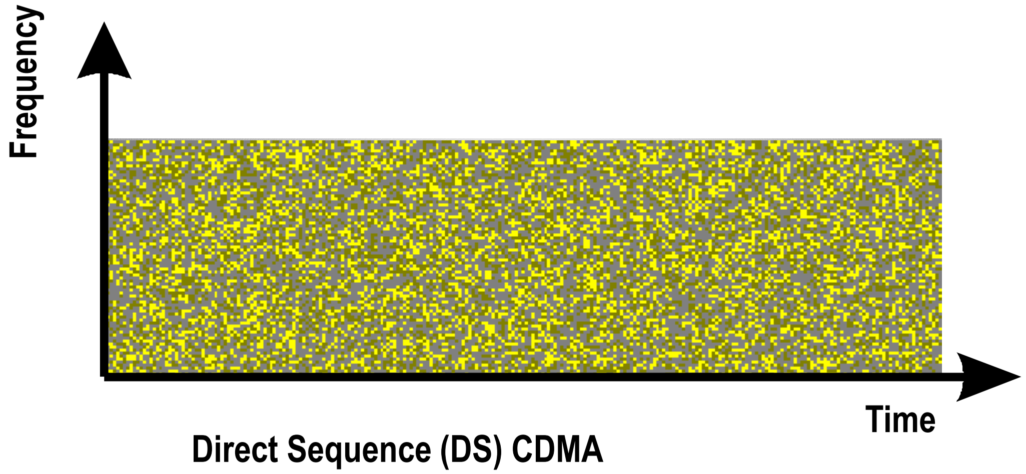
WCDMA Carrier



5+5 MHz in FDD mode
5 MHz in TDD mode

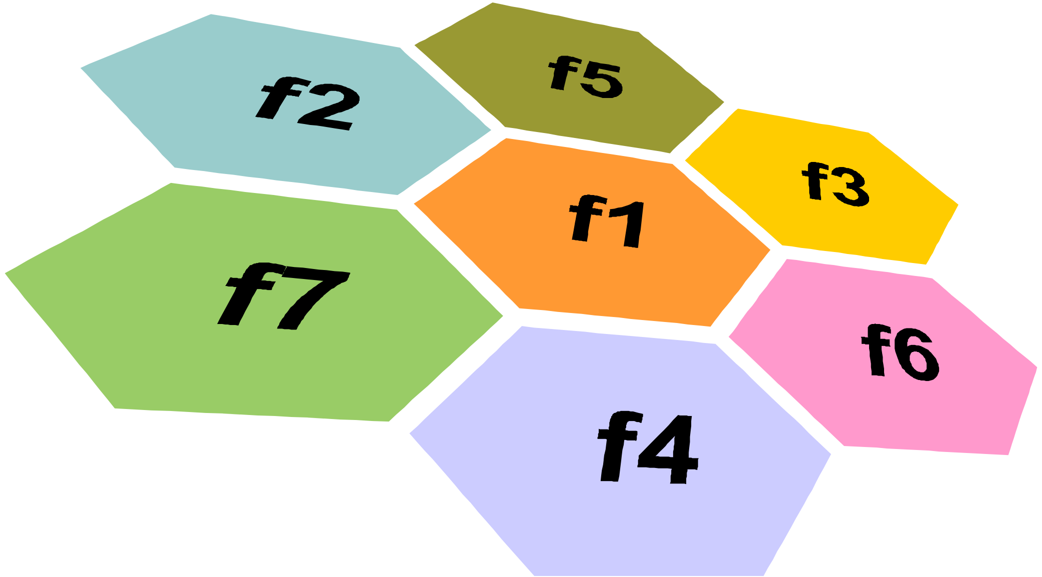


Users share same time and frequency

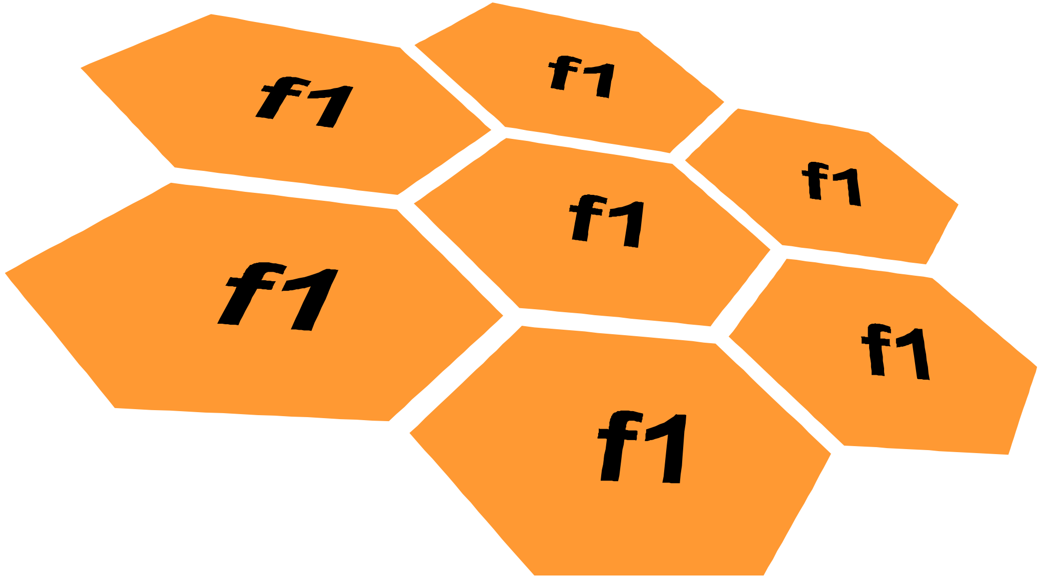


UMTS & GSM Network Planning

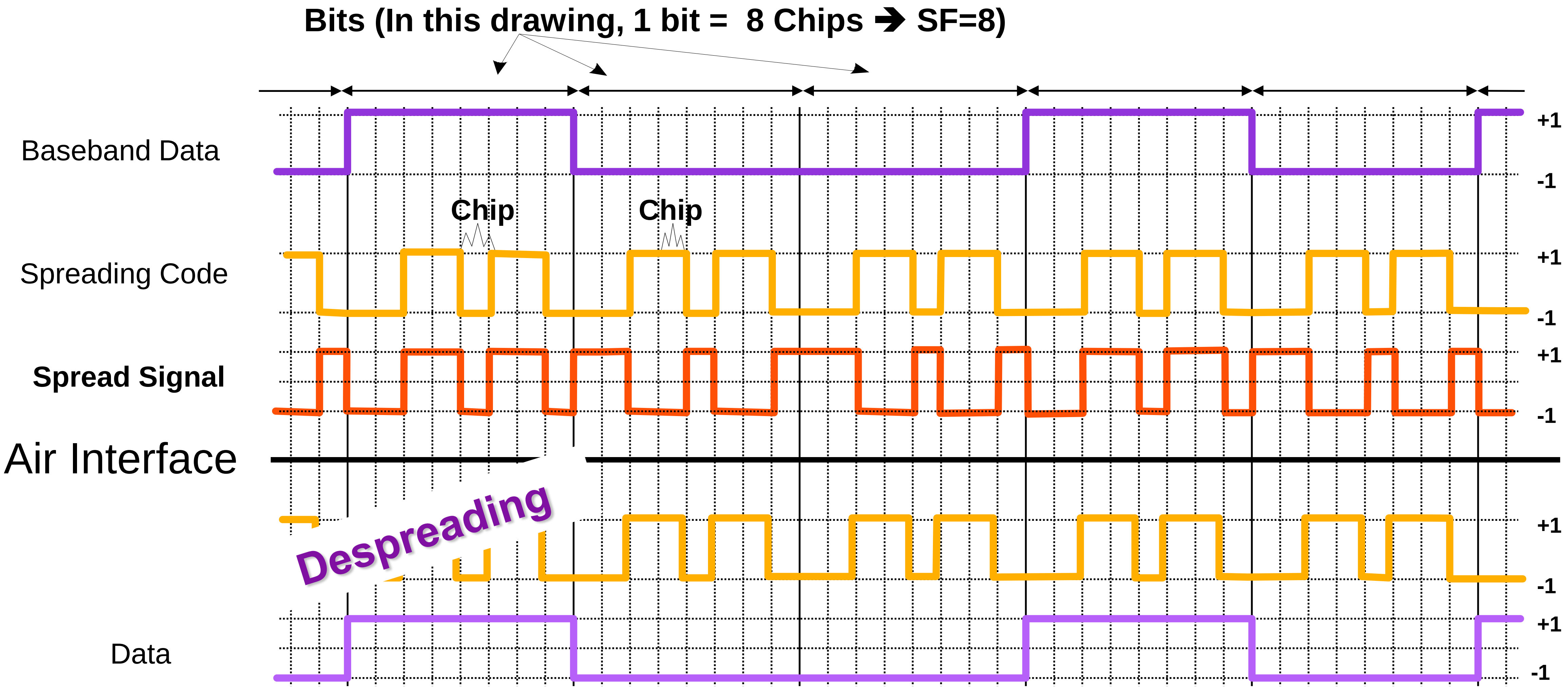
GSM900/1800:



3G (WCDMA):



CDMA principle - Chips & Bits & Symbols



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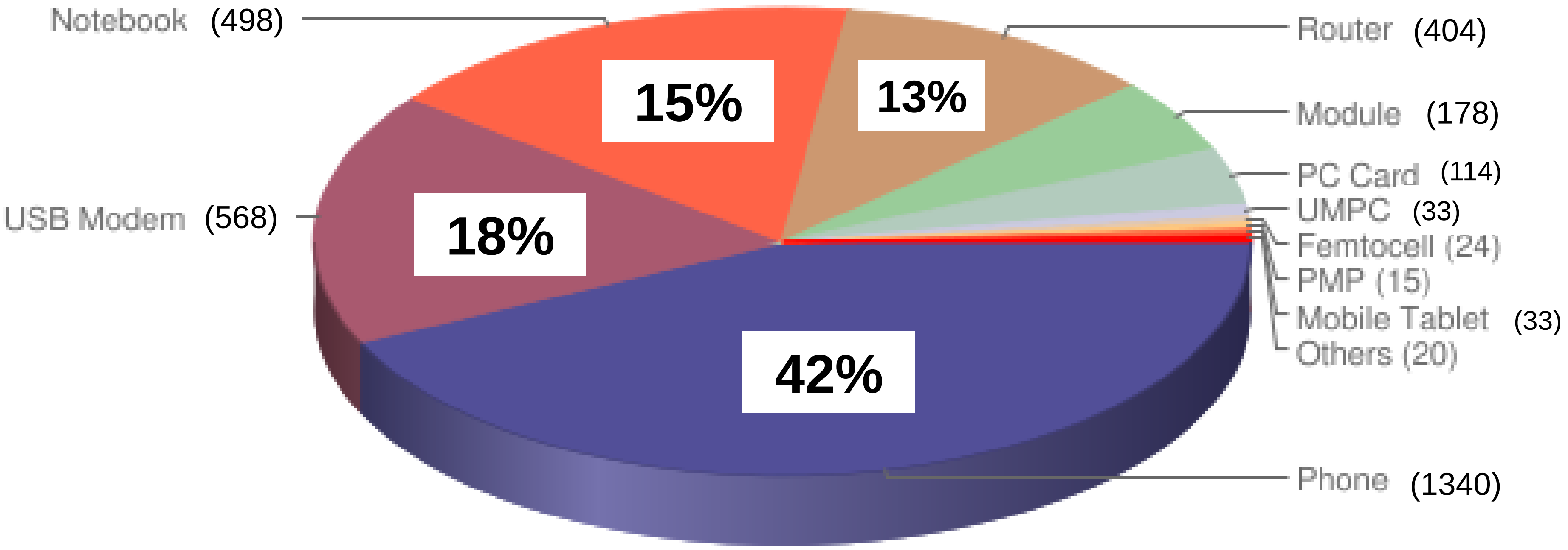
HSPA device landscape (GSA July, 2011)

3227 different kind of HSPA-enabled devices



TRUE world-market HSPA devices available

Examples:

Quad-band

850/900/1900/2100

iPad 2

iPhone 4
iPhone 4S

Nokia C6

Samsung Galaxy S II

Nokia Lumia 800

Sierra Wireless 504

Option Globetrotter 441

Option ICON 452

850/AWS/1900/2100

Five-band !!

850/900/AWS/1900/2100

Nokia C7

Nokia N8

Samsung Galaxy Nexus

Nokia E7

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Clearly below 100 Euros HSPA phones now available

Samsung Hero E3210
Dual-band HSPA 3.6 Mbps
Quad band EDGE
~ 40 €

Samsung Hero E3213
Dual-band HSPA 3.6 Mbps
Quad band EDGE
~ 50 €

Nokia Asha 300
Quad-band HSPA 10.2 Mbps
Quad EDGE, Dual SIM
~ 75 €

Huawei Ideos X1
Dual-band HSPA 7.2 Mbps
Android 2.2
~ 90 €

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HSPA device categories and max theoretical data rates

HSDPA Categories (Downlink)	
Cat6	3.6 Mbps, with 16QAM
Cat8	7.2 Mbps, with 16QAM
Cat9	10.1 Mbps, with 16QAM
Cat10	14.4 Mbps, with 16QAM
Cat14	21 Mbps, with 64QAM
Cat18	28 Mbps, with MIMO and 16QAM
Cat20	42 Mbps, with MIMO and 64QAM
Cat24	42 Mbps, DC-HSDPA and 64QAM
Cat28	84 Mbps, DC-HSDPA and 64QAM and MIMO
Cat32	168 Mbps, MC-HSDPA and 64QAM and MIMO

HSUPA Categories (Uplink)	
Cat2	1.4 Mbps
Cat5	2.0 Mbps
Cat6	5.76 Mbps
Cat7	11.5 Mbps, with 16QAM
Cat8	11.5 Mbps, DC-HSUPA, 2x Cat6
Cat9	23 Mbps, DC-HSUPA, 2x Cat7

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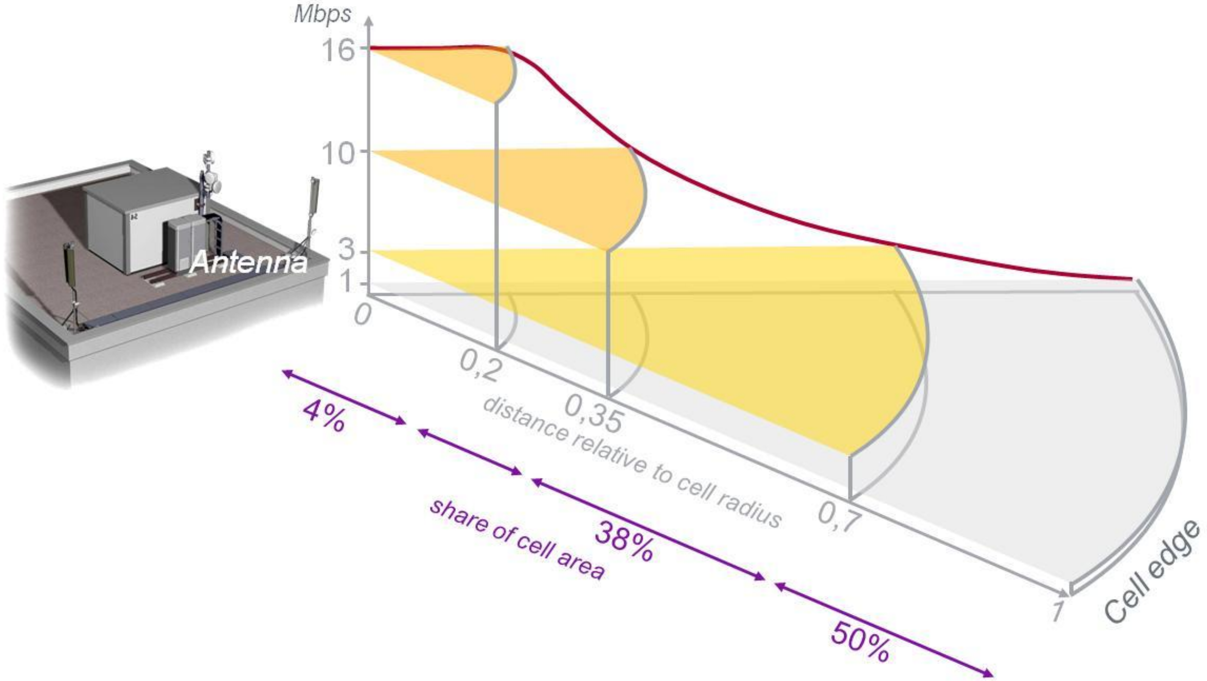
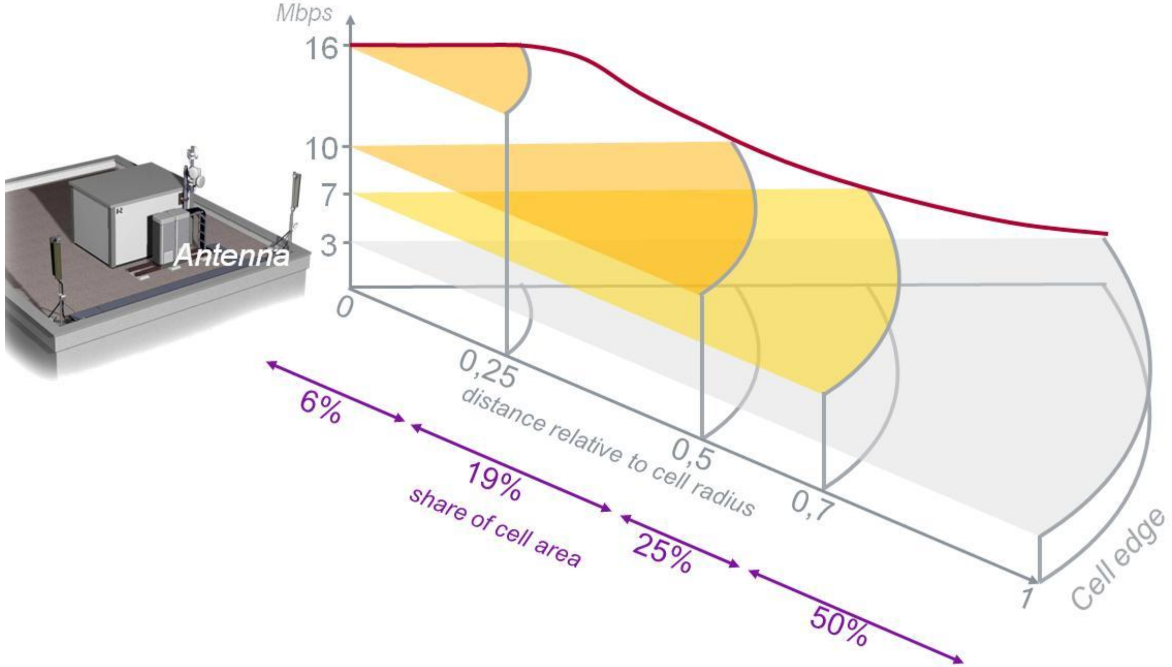
HSPA+ radio performance basics

- HSDPA peak rate depends on adaptive modulation, coding and UE category
- BTS selects modulation and coding based on reported signal quality (affected by e.g. distance from BTS, load in neighboring cells and UE performance)



HIGH LOAD neighboring cells
64 QAM, no MIMO, no DC-HSPA



LOW LOAD neighboring cells
64 QAM, no MIMO, no DC-HSPA

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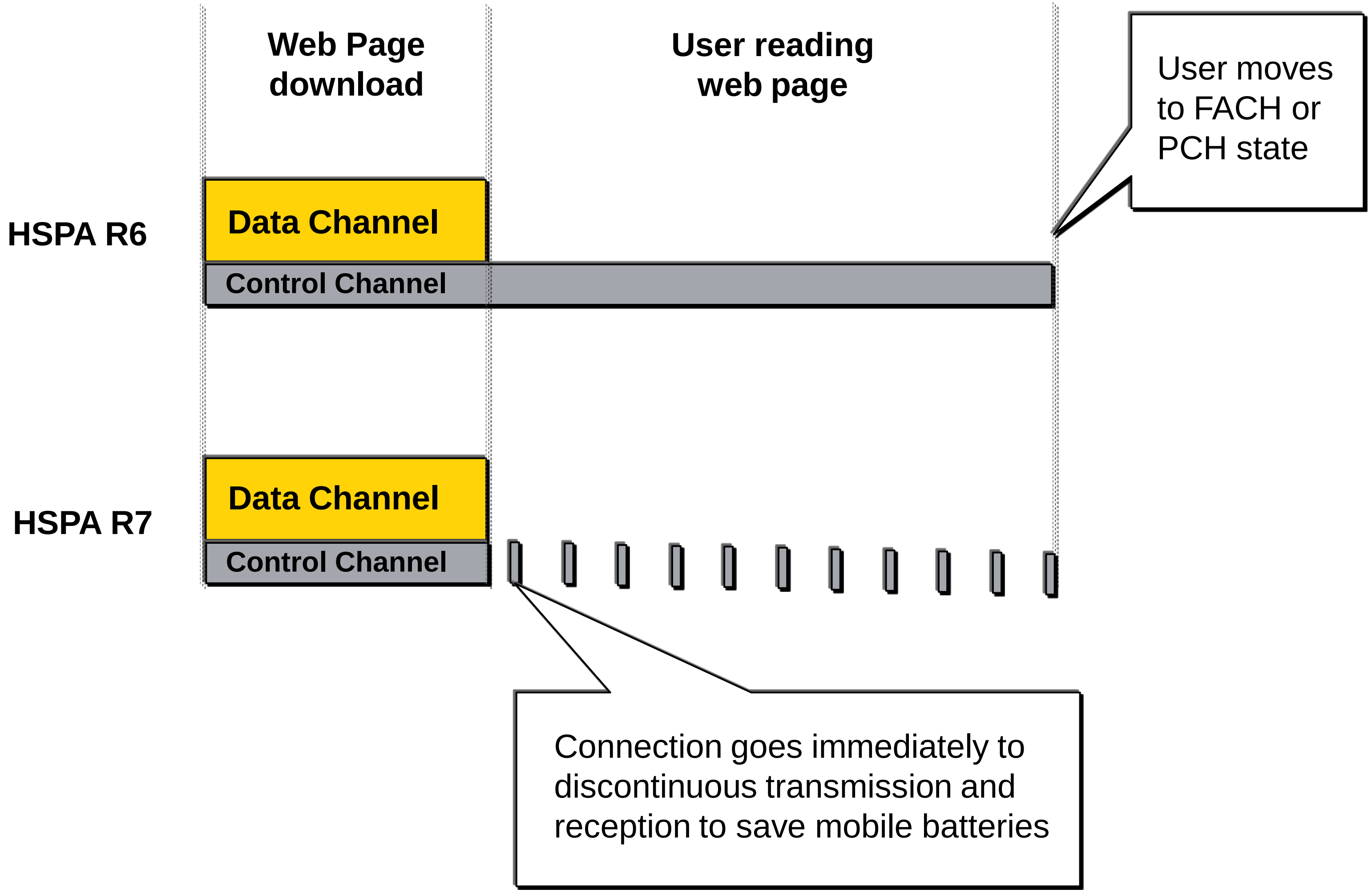
Discontinuous Transmission and Reception (DTX/DRX)



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Dual Cell HSDPA and HSUPA

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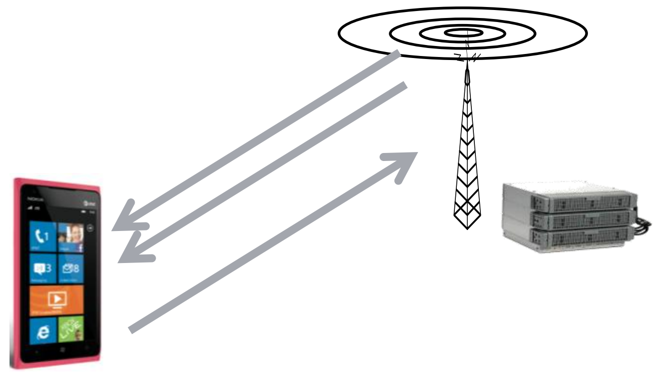
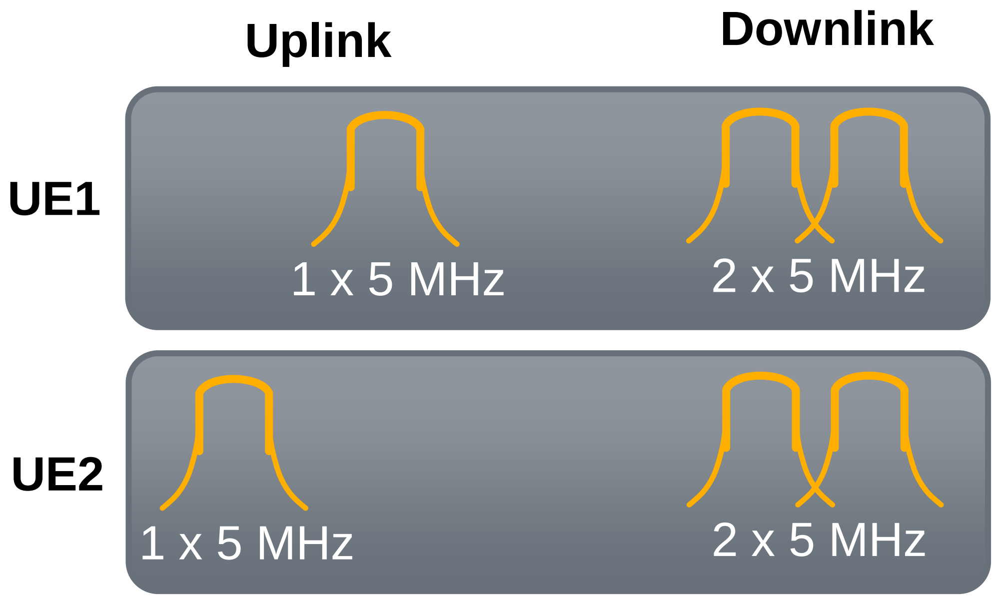
- DC-HSDPA is a Release 8 enhancement. It provides a method to aggregate two adjacent carriers in the downlink.

- Enables transmission of 2 adjacent carriers of 10MHz bandwidth to single terminal.

- The main reason behind DC-HSDPA, i.e. multi-carrier, is to improve resource utilization and therefore increase spectrum efficiency. This is achieved by having joint resource allocation, as well as load balancing across both carriers.





Downlink DC HSDPA concept

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Dual Cell HSDPA and HSUPA

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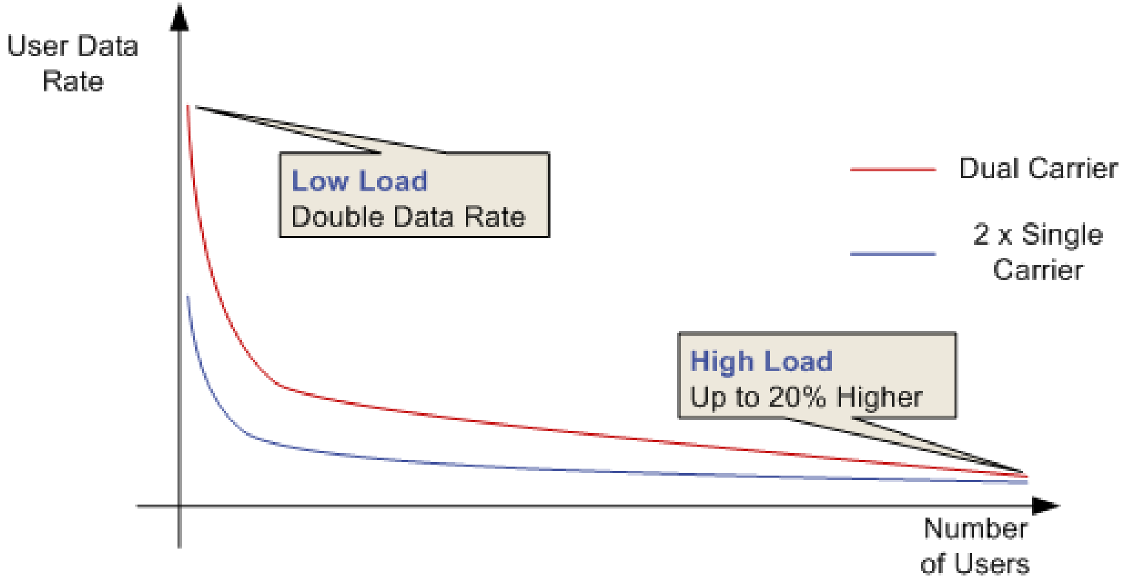
- DC-HSDPA can double data rate at low loading because the user can access the capacity of two carriers instead of just one. The relative benefit decreases when loading increases.

- There is still some capacity benefits at high load due to frequency domain scheduling and dynamic load balancing between carriers (if both carrier is not 100% loaded at all time).



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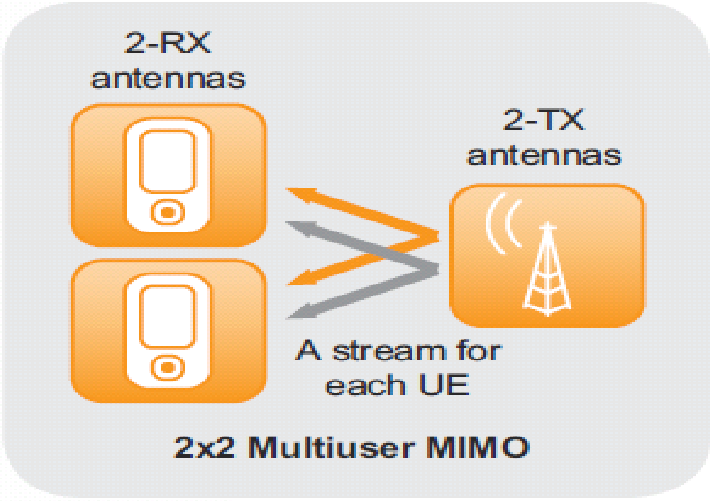
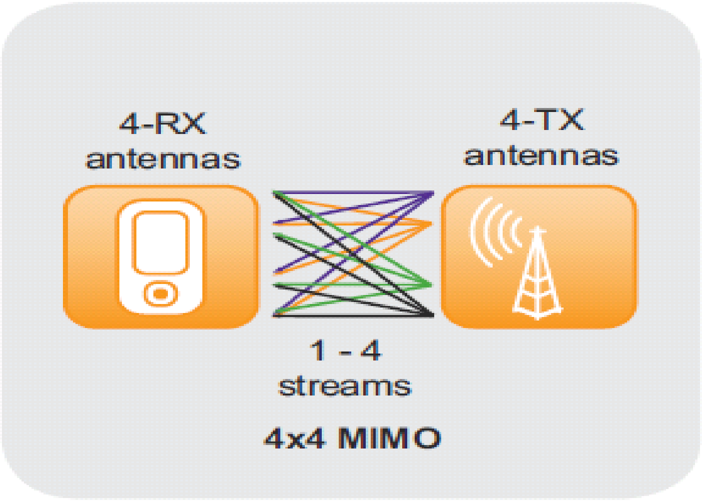
MIMO Evolution

- Multi-antenna transmission and reception increases
  - peak data rates,
  - cell throughput and
  - cell edge data rates

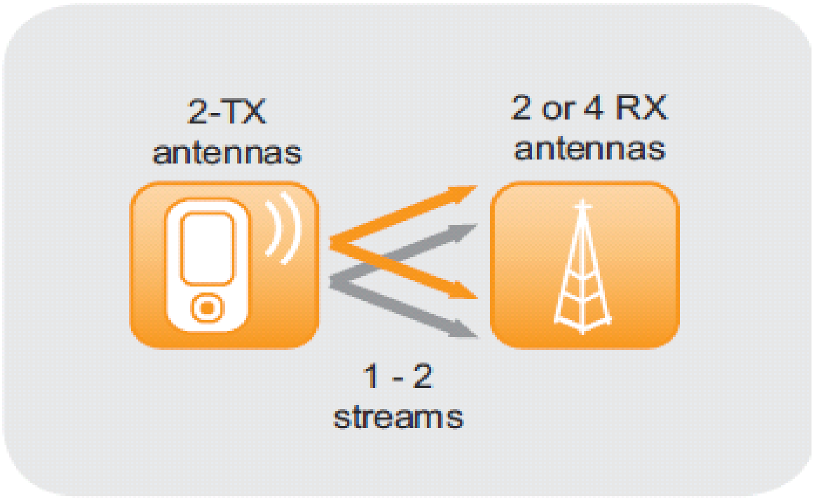
Downlink Multiuser MIMO



Downlink 4x4 MIMO



Uplink 2x2 MIMO



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Dual Cell vs MIMO

	Dual Carrier	MIMO
Peak Rate	42Mbps	42Mbps
Improvement in Spectral Efficiency	20% - Due to improved scheduling in the frequency domain and increased trunking gain.	10% - Since two antennas.
Data Rate Improvement	The gain is similar all over the cell area.	Largest gain close to Node B.
Node B RF Requirements	Single Power Amplifier per sector.	Needs two Power Amplifiers per sector.
UE RF Requirements	Possible with 1 antenna terminal.	2 antennas required.

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Multicarrier HSPA Evolution

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3GPP Release 7:

UE can receive and transmit on single 5 MHz carrier

3GPP Release 8-9:

UE can receive and transmit two adjacent 5 MHz carriers

3GPP Release 10:

UE can receive four 5 MHz carriers

Uplink **Downlink**

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Multiband HSPA Evolution

3GPP Release 7:

UE can receive and transmit on single band

3GPP Release 9:

UE can receive on two bands

3GPP Release 10:

UE can receive on two bands and up to four carriers

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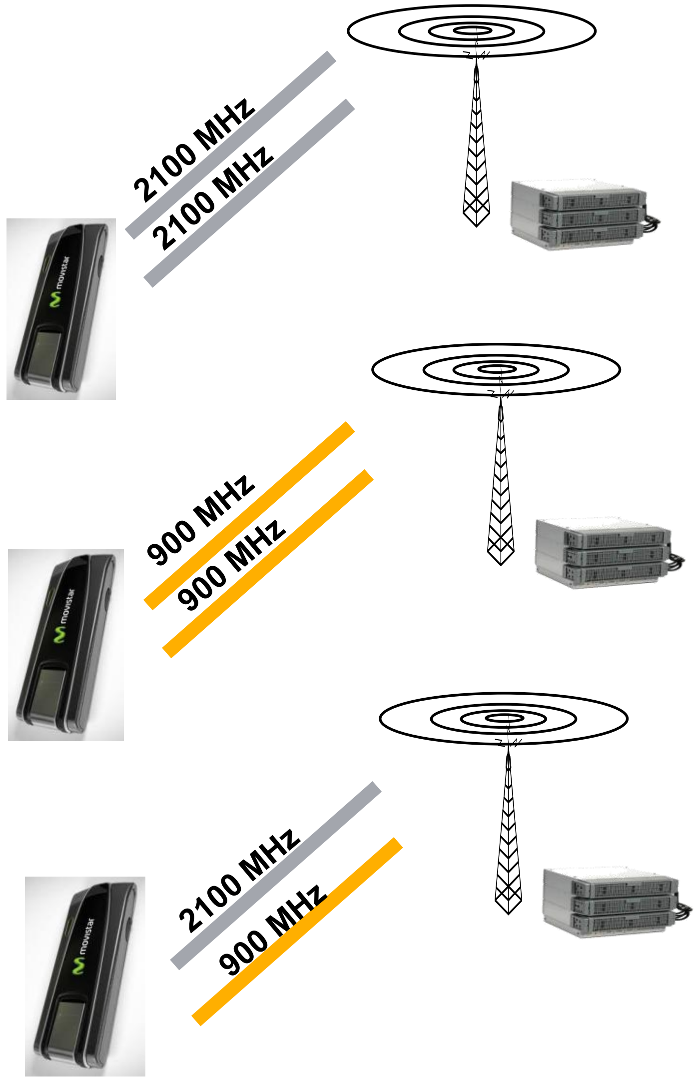
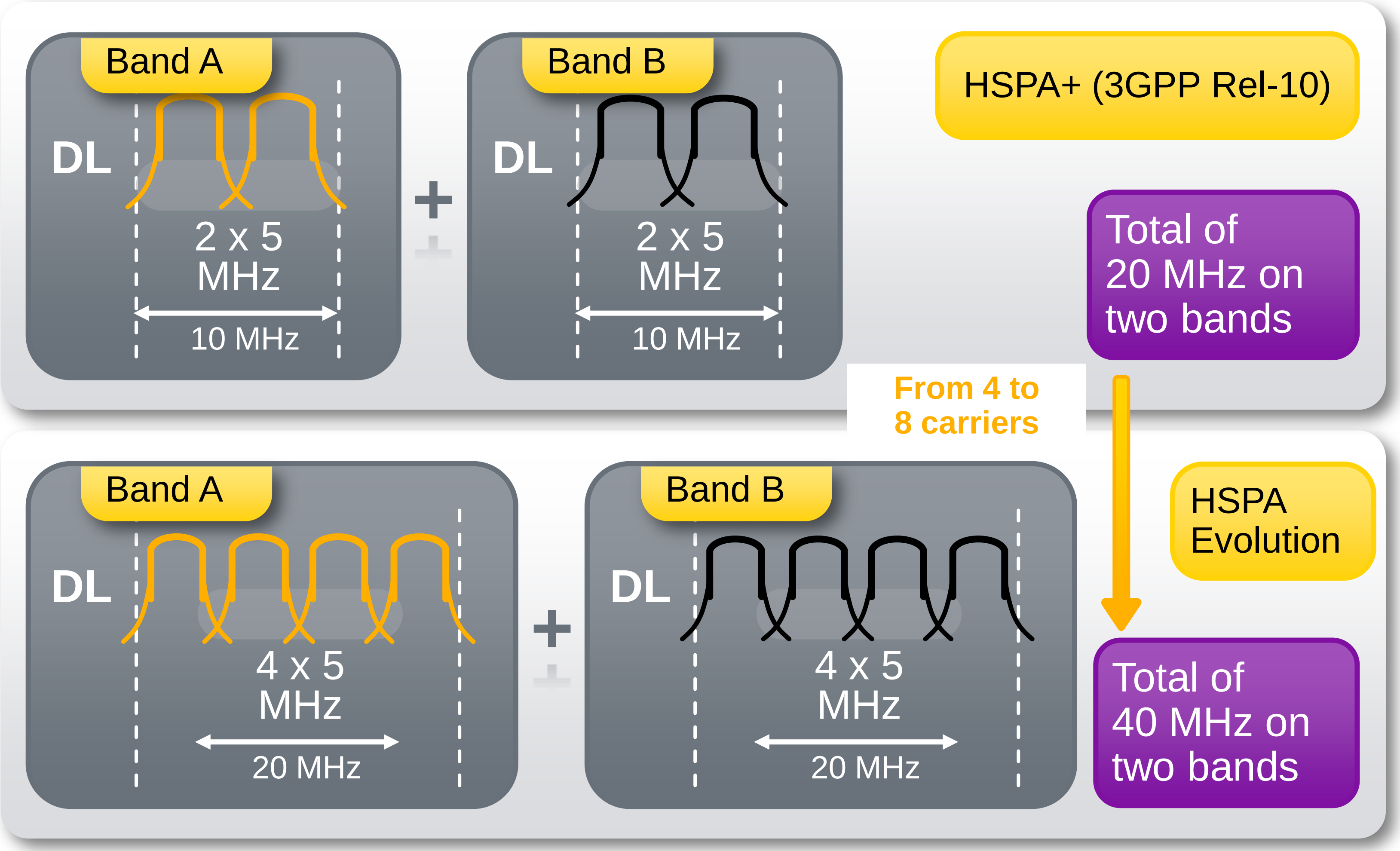
DC-HSPA on 2100, 900 and 2100+900 MHz (dual-band DC)



- DC-HSPA 42 Mbit/s device available currently in the market can support aggregation of two HSPA-carriers on the 2100 MHz band
- Technology-wise DC-HSPA on 900 MHz could be done but typically not included to the early devices/ chipset due lack of operator demand
  (not many operators that can free 900 for two HSPA-carriers)
- Devices capable for dual-band DC-HSPA 42 Mbit/s are expected earliest year 2013

Multicarrier aggregation of up to 8 carriers on two bands for up to 672 Mbps

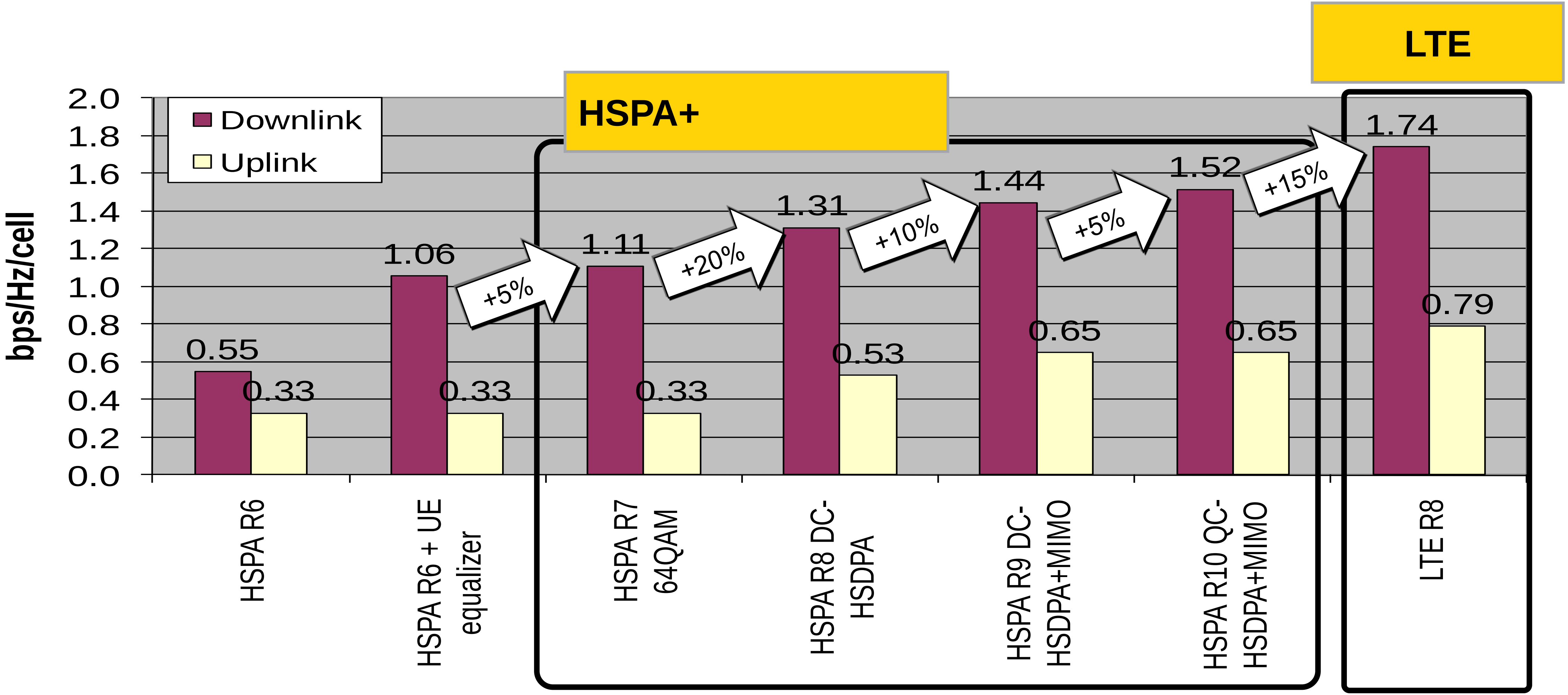


Expected band combinations

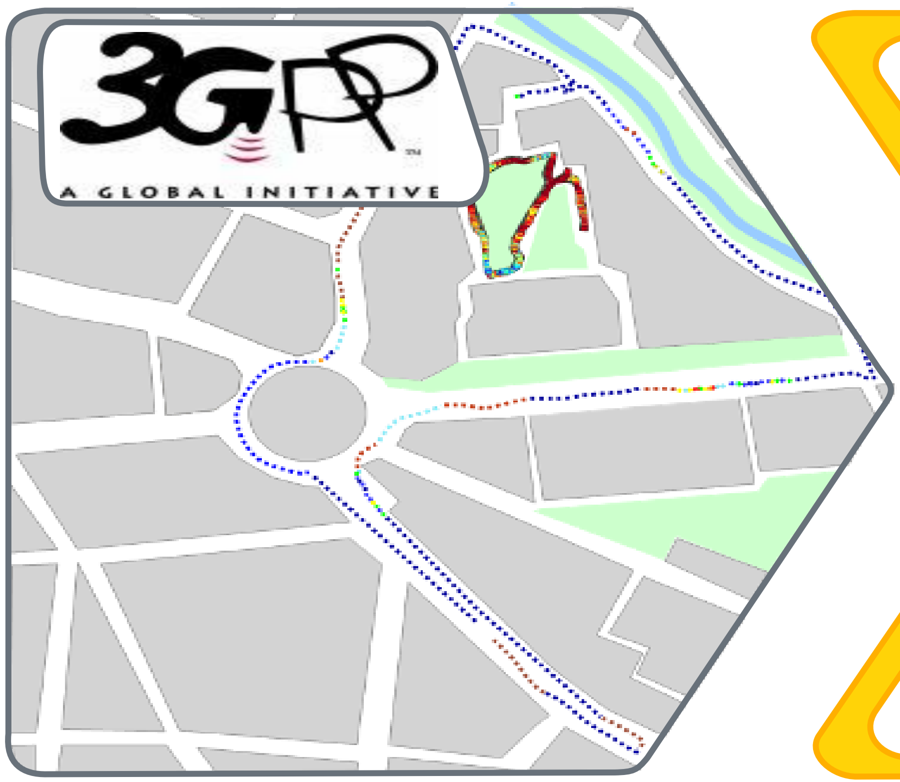
Band A	Band B
1900 MHz	2100/1700 MHz
1900 MHz	850 MHz
2100 MHz	1500 MHz
2100 MHz	900 MHz
2100 MHz	850 MHz

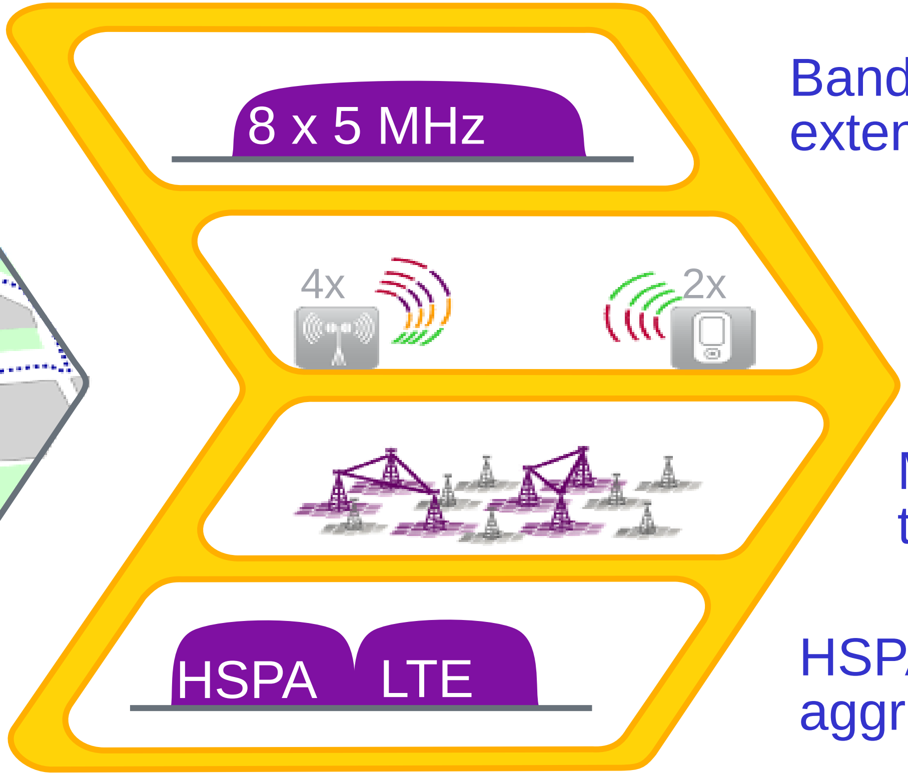
- 8-carrier with 4x4 MIMO: 672 Mbps peak rate
- Spectral efficiency improvement of up to 100%

Spectral Efficiency Evolution



Long Term HSPA Evolution – Technology Components





Bandwidth extension

MIMO

Multi-cell transmission

HSPA + LTE aggregation

Similar technical solutions in Long Term HSPA Evolution and in LTE Advanced

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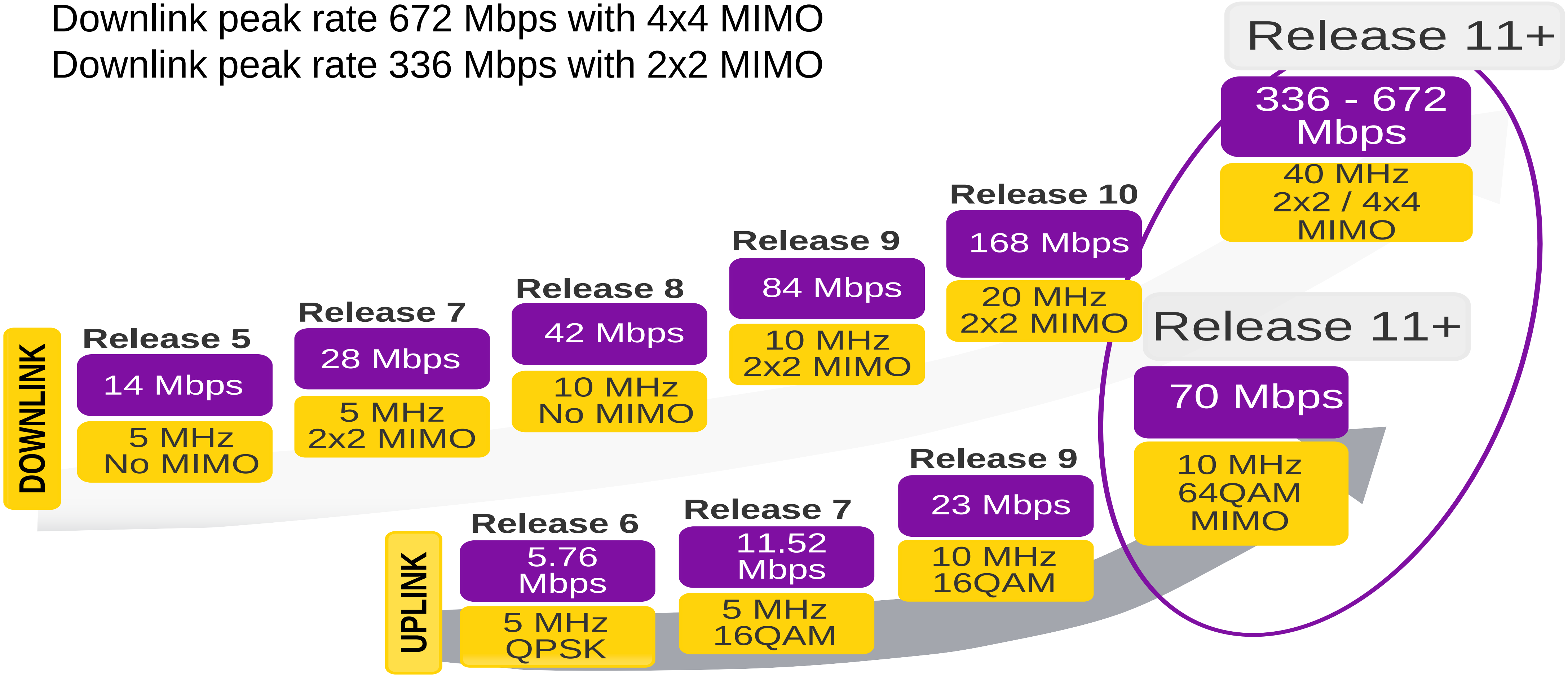
HSPA Peak Data Rate Evolution

- Downlink peak rate 672 Mbps with 4x4 MIMO
- Downlink peak rate 336 Mbps with 2x2 MIMO



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- Introduction
- WCDMA/HSPA/HSPA+
- **LTE**
  - **Introduction**
  - LTE Spectrum
  - Radio Access Overview
  - Core Network Overview
  - Voice over LTE (VoLTE)
  - QoS in LTE
  - Self Organizing Network (SON)
- LTE-Advanced
- Summary

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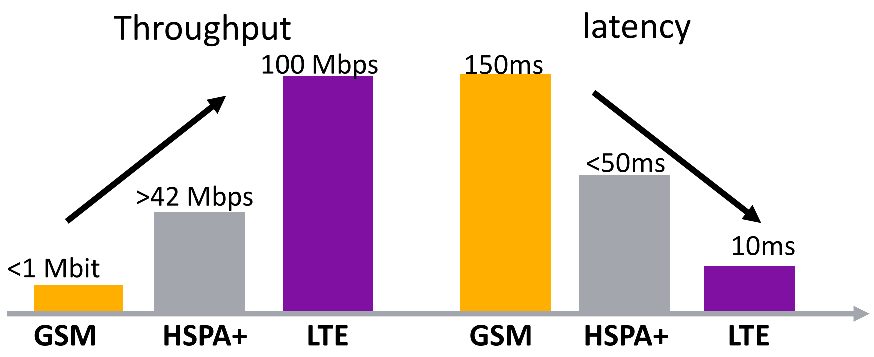
WHY LTE?

Superior mobile broadband user experience



Industry commitment behind the ecosystem

> 380 million LTE subscribers by 2015
Forecast for LTE lead markets by Research and Markets

119 LTE networks expected to be in commercial operation by end 2012

226 LTE network operator commitments in 76 countries

Technology convergence

- GSM
- WCDMA
- CDMA
- WiMAX
- TD-SCDMA

FDD LTE

>90% harmonized in 3GPP

TD-LTE

LTE Advanced

Extensive range of radio spectrum support

23 different FDD frequency band options
11 different TDD frequency band options

Single operator may deploy both FDD+TDD LTE for maximum utilization of spectrum assets

+ new ones still being specified both for new band deployment and re-farming cases

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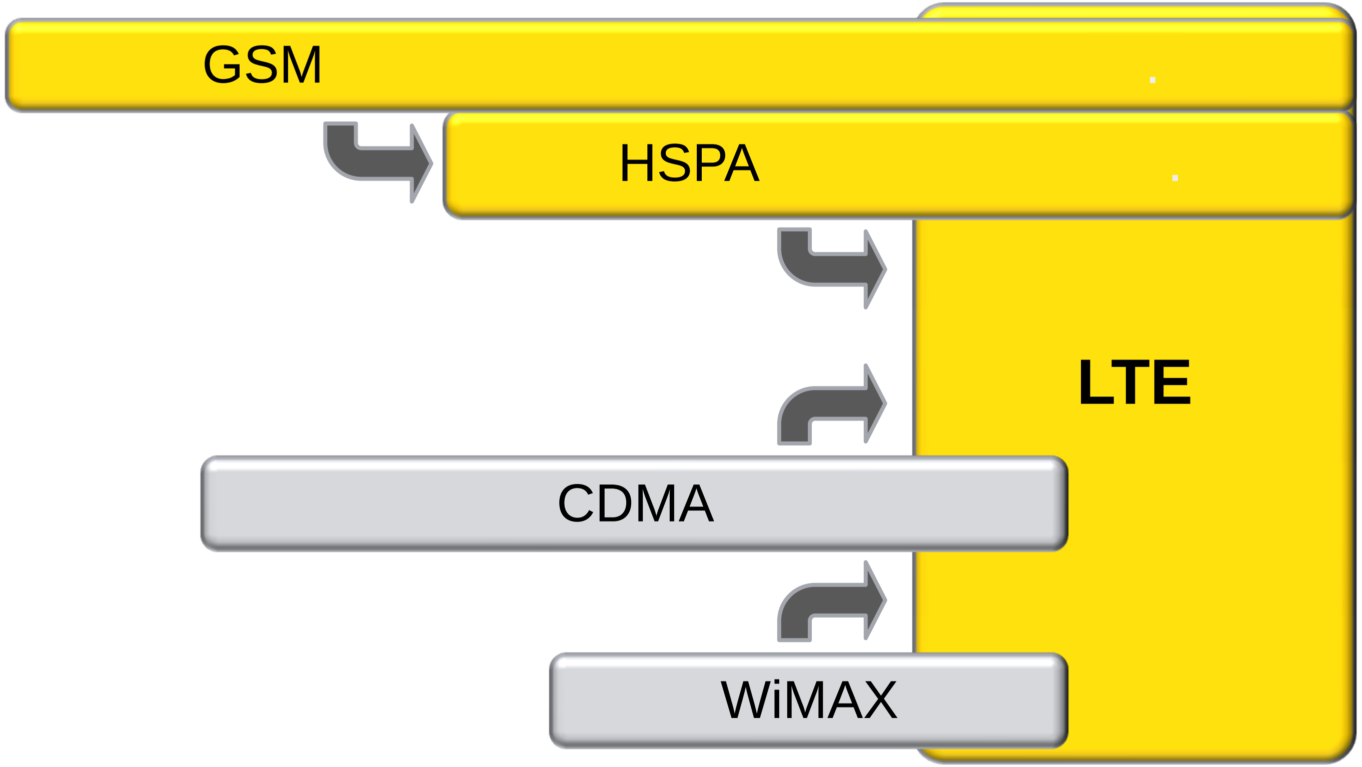
LTE will be THE Mobile Broadband Radio Solution



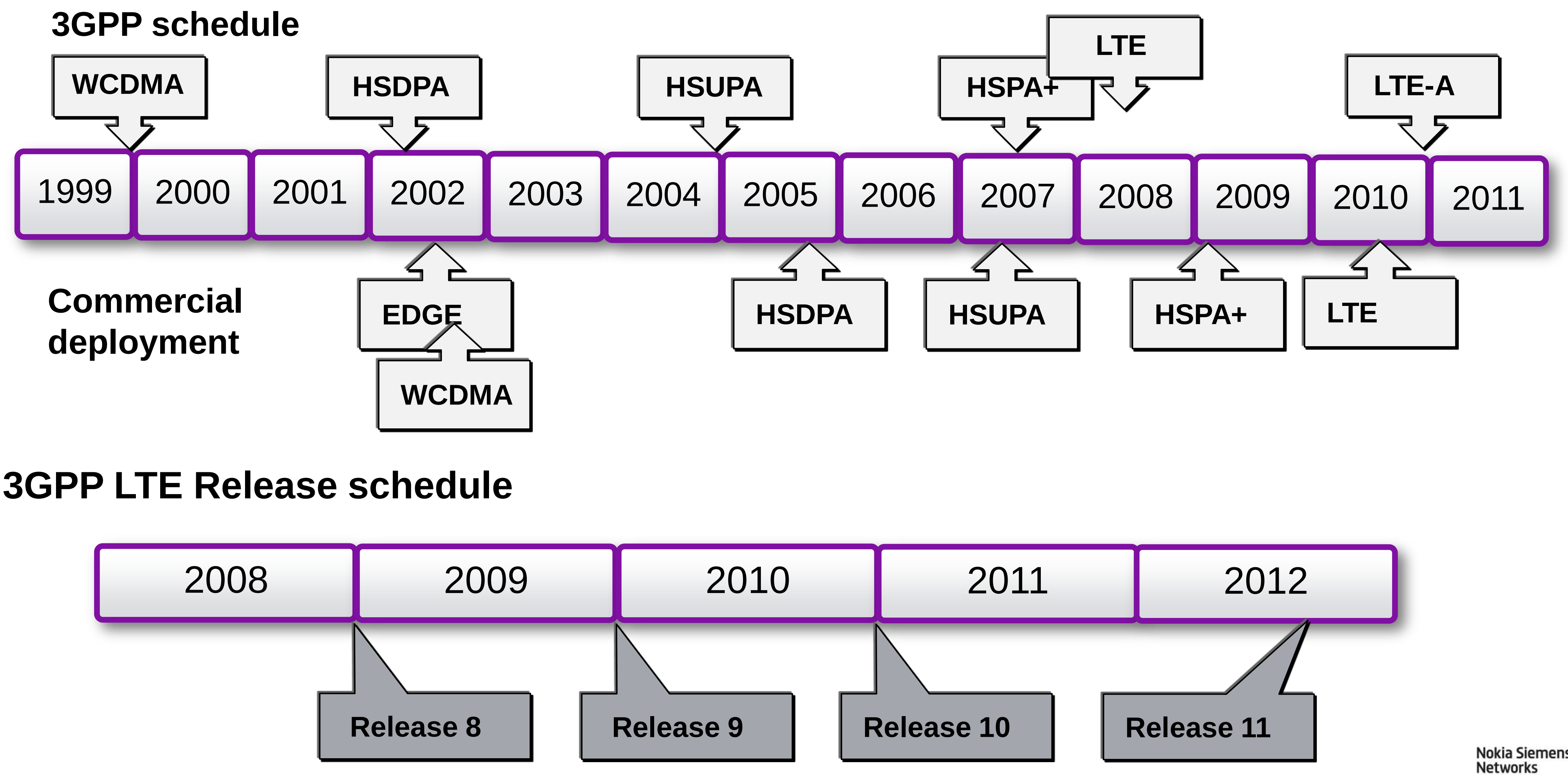
- All HSPA and GSM operators deploy LTE
- HSPA and GSM remain in parallel to LTE for many years
- All CDMA operators migrate to LTE to get rid of CDMA soon
- All WiMAX operators migrate to LTE to get rid of WiMAX soon

- Harmonized Frequency Division Duplex (FDD) and Time Division Duplex (TDD) modes

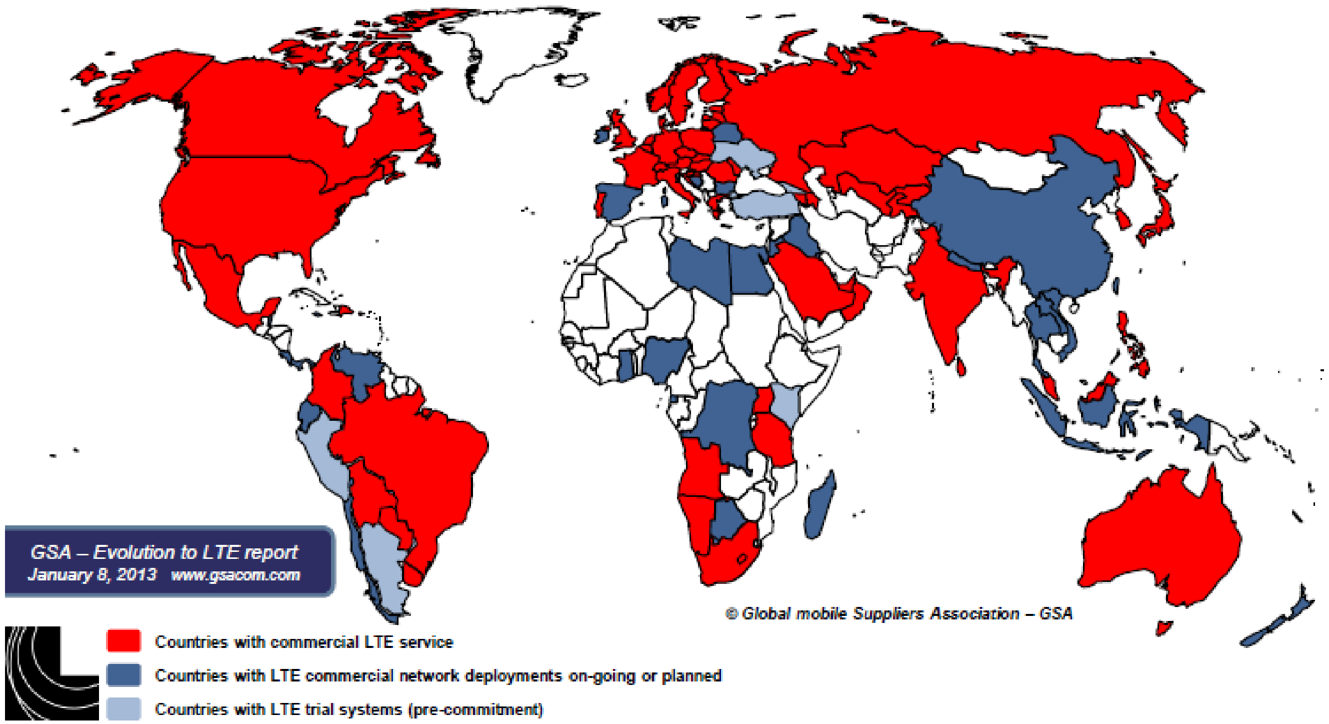
Motivation and Targets for LTE

- Spectral efficiency 2 to 4 times more than with HSPA Rel-6
- Peak rates exceed 100 Mbps in downlink and 50 Mbps in uplink (which is 10 times more than HSPA Rel-6)
- Enable a round trip time of < 10 ms
- Packet switched optimized
- High level of mobility and security
- Optimized terminal power efficiency
- Frequency flexibility with allocations from below 1.5 MHz up to 20 MHz

3GPP Standard and Release schedule



LTE market status



- 164* operators have commercially launched LTE in 67 countries
- 248 commercial LTE networks in 87 countries expected by end 2013
- LTE re-affirmed by GSA as the fastest growing mobile system technology ever

Source: GSA Evolution to LTE report (April 7th, 2013), additionally COTA, Spain.

- 361 commercial LTE network commitments in 114 countries

- 1bn LTE connections by early 2017
- Mainly driven by LTE smartphones

Forecast by Strategy Analytics (May 2012)

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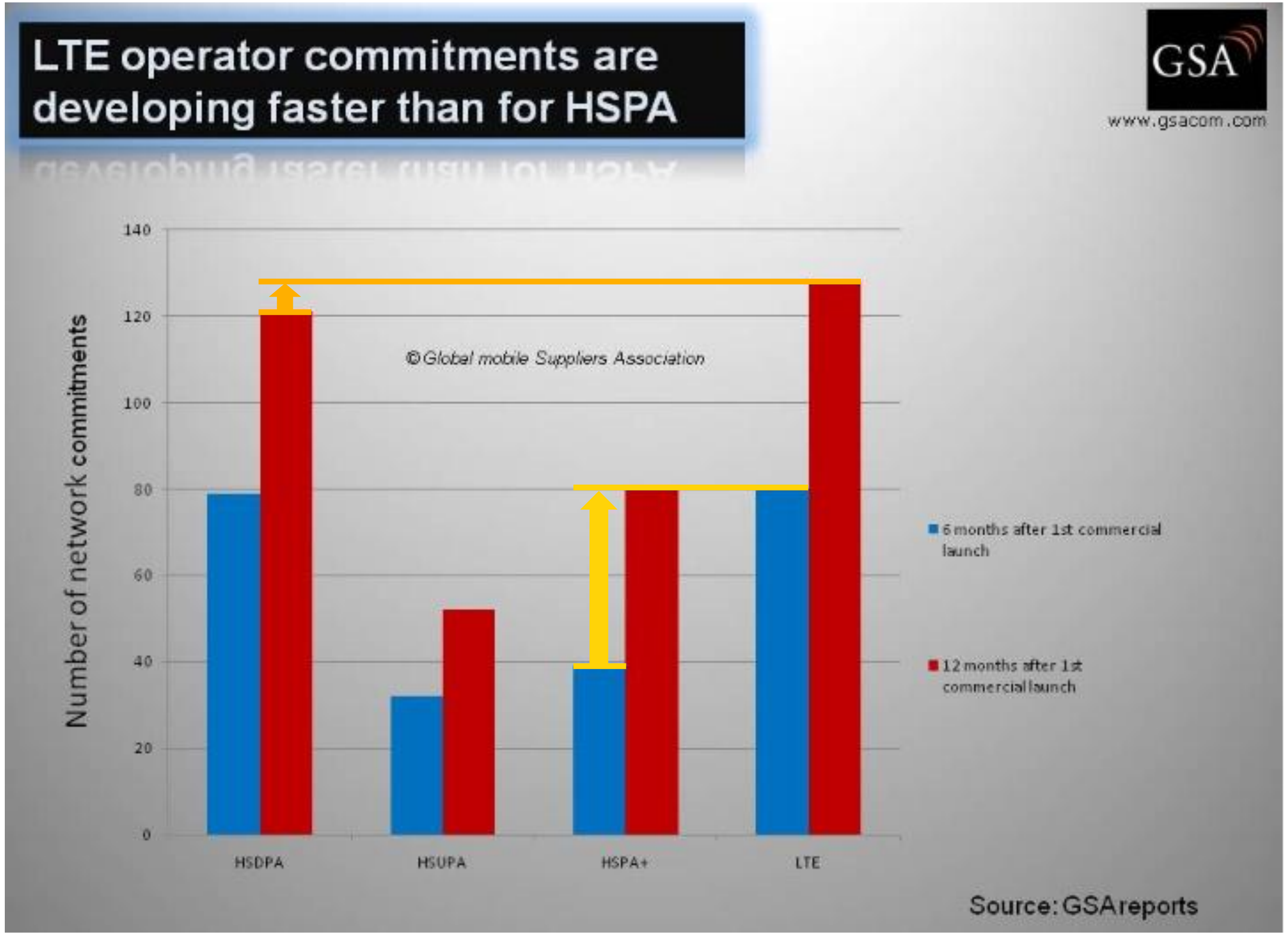
LTE market momentum



LTE is faster adopted than any previous mobile broadband technology

12 months after 1st commercial LTE launch (Telia), more operator commitments to LTE than HSPA commitments 12 months after 1st commercial HSDPA launch

6 months after 1st commercial launch, twice as many commitments for LTE than for HSPA+

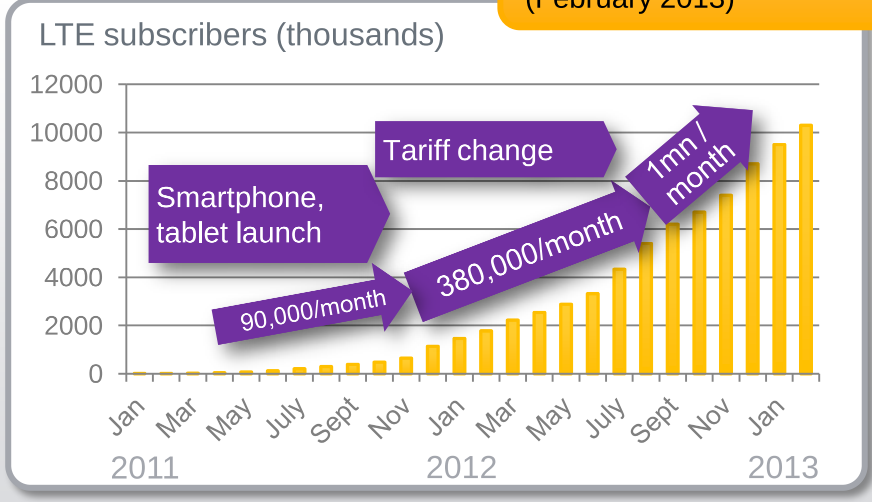
Time to reach 1bn connections:

Estimates by Strategy Analytics, May 2012

LTE subscriber and coverage growth in advanced mobile broadband markets

NTT docomo, Japan

10.3mn LTE subs.
(February 2013)



1.3mn new LTE subs. in December 2012

Telia, Denmark

- Oct. 10, 2011: 50% population coverage
- End 2011: 75% population coverage

Dec 2012:

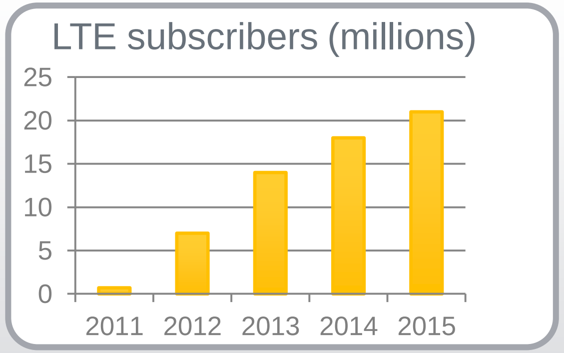
- Korea: >30% LTE subscriber penetration
- Japan: LTE launch with iPhone 5 launch (Softbank, KDDI)

LG U+, South Korea

99% population coverage reached (March 2012)

4.5 mn LTE subs.
>40% penetration
(January 2013)

SK telecom, South Korea



65% of total data traffic will be handled by LTE networks in 2014

8.3 mn LTE subs.
(February 2013)

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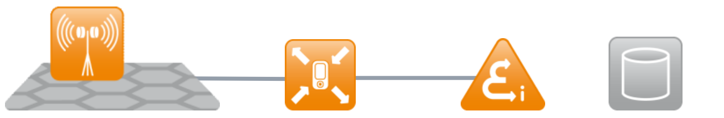
Basic Concepts / Architecture

LTE / SAE introduces the mechanism to fulfill the requirements of a next generation mobile network

Flat Overall Architecture

- 2-node architecture
- IP routable transport architecture

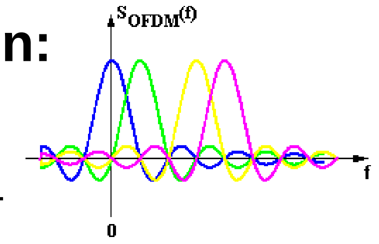


Improved Radio Principles

- peak data rates [Mbps] 173 DL , 58 UL
- Scalable BW: 1.4, 3, 5, 10, 15, 20 MHz
- Short latency: 10 – 20 ms

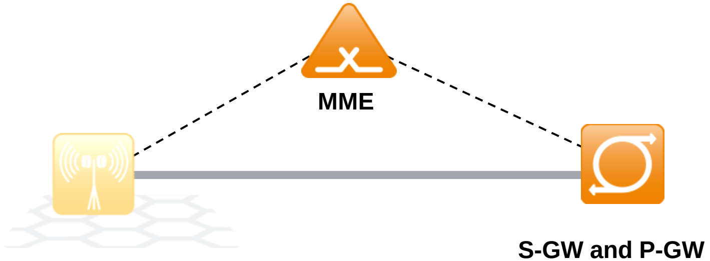
RF Modulation:

- OFDMA in DL
- SC-FDMA in UL



New Core Architecture

- Simplified Protocol Stack
- Simple, more efficient QoS
- UMTS backward compatible security



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LTE spectrum & ecosystem

LTE FDD

- **Early FDD LTE ecosystem (commercial networks)**
  - → **2600** (Europe, APAC)
  - → **2100** (Japan)
  - → **1900 PCS** (US)
  - → **1800** (GSM refarming)
  - → **1700/2100 AWS** (NAM incl. Canada)
  - → **850** (South Korea)
  - → **800 Digital Dividend** (Europe, MEA)
  - → **Upper 700 MHz, C** (Verizon)
  - → **Lower 700 MHz, B/C** (AT&T)

TD-LTE

- **Early TD-LTE ecosystem mainly building on**
  - → **2300** (MEA, India, China, APAC, Russia)
  - → **2600** (China, LatAM, Europe)

LTE FDD

Band	MHz	Uplink MHz	Downlink MHz	
1	**2x60**	**1920-1980**	**2110-2170**	**UMTS core**
2	**2x60**	**1850-1910**	**1930-1990**	**US PCS**
3	**2x75**	**1710-1785**	**1805-1880**	**GSM 1800**
4	**2x45**	**1710-1755**	**2110-2155**	**NAM AWS**
5	**2x25**	**824-849**	**869-894**	**850**
7	**2x70**	**2500-2570**	**2620-2690**	**2600 FDD**
8	2x35	880-915	925-960	GSM 900
9	2x35	1749-1784	1844-1879	Japan, Korea 1700
10	2x60	1710-1770	2110-2170	US AWS extension.
11	2x20	1427.9-1447.9	1475.9-1495.9	Japan 1500
12	2x18	698-716	728-746	US
13	**2x10**	**777-787**	**746-756**	**Verizon**
14	2x10	788-798	758-768	US – Public Safety
17	**2x12**	**704-716**	**734-746**	**AT&T**
18	2x15	815-830	860-875	Japan – 800 (KDDI)
19	2x15	830-845	875-890	Japan – 800 (DoCoMo)
20	**2x30**	**832-862**	**791-821**	**EU 800 DD, MEA**
21	2x15	1448-1463	1496-1511	Japan 1500
22	2x80	3410-3490	3510-3590	3.5 GHz FDD
23	2x20	2000-2020	2180-2200	US S-band
24	2x34	1626.5-1660.5	1525-1559	US (LightSquared)
25	2x65	1850-1915	1930-1995	US PCS extension (Sprint)
26	2x35	814-849	859-894	850 extension (Korea-KT, Sprint)

TD-LTE

Band	MHz	Uplink MHz	Downlink MHz	
33	1x20	1900-1920	1900-1920	UMTS core – TDD
34	1x15	2010-2025	2010-2025	UMTS core – TDD, China TD/SCDMA
35	1x60	1850-1910	1850-1910	US (band 2 – TDD variant)
36	1x60	1930-1990	1930-1990	US (band 2 – TDD variant)
37	1x20	1910-1930	1910-1930	US PCS centre-gap
38	**1x50**	**2570-2620**	**2570-2620**	**China, LatAM, Europe**
39	1x40	1880-1920	1880-1920	China PHS
40	**1x100**	**2300-2400**	**2300-2400**	**MEA, India, China, Russia**
41	1x194	2496-2690	2496-2690	US (Clearwire)
42	1x200	3400-3600	3400-3600	3.4/5 GHz – TDD
43	1x200	3600-3800	3600-3800	3.7/8 GHz – TDD

Source: TS 36.101; ***commercialized bands***

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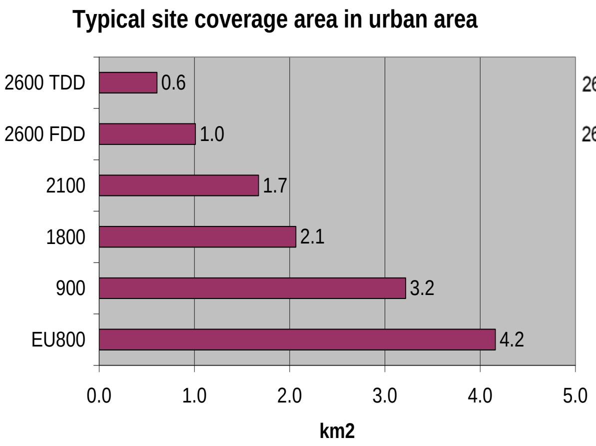
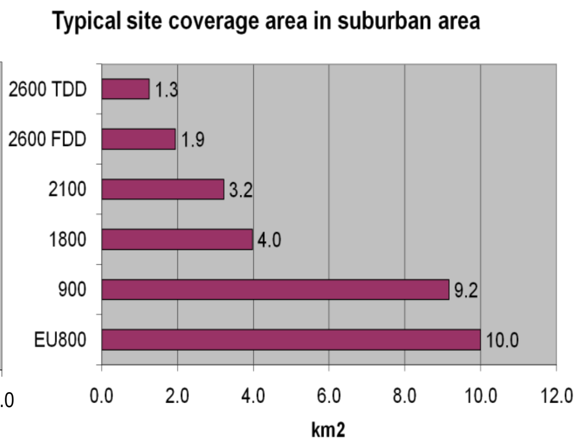
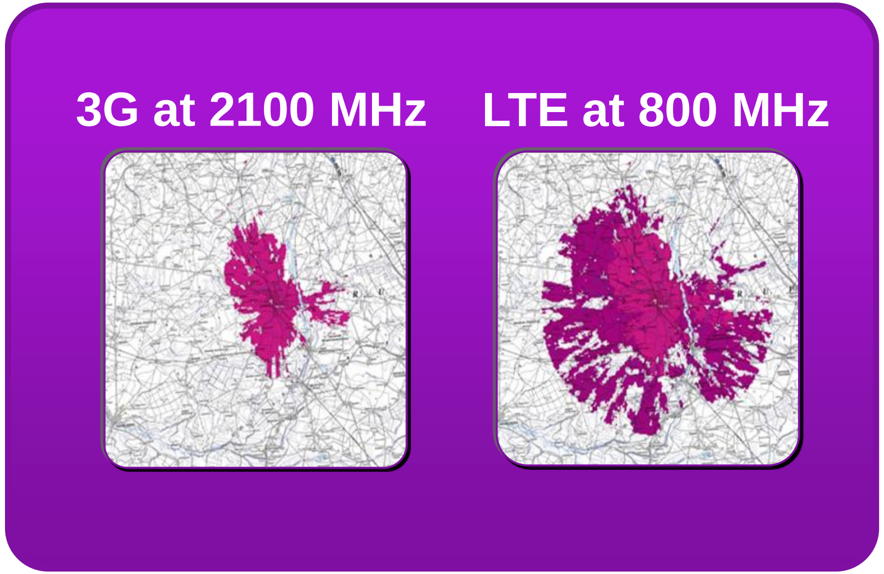
Coverage – Low Band and FDD best for wide area
LTE - FDD 800 MHz





BS antenna height [m]	30
MS antenna height [m]	1.5
Standard Deviation [dB]	8.0
Location Probability	95 %
Slow Fading Margin [dB]	8.8
Correction factor [dB]	-5
Indoor loss [dB]	15

Example: LTE 800 Coverage (Germany)



> 3 – times more coverage on 800 MHz

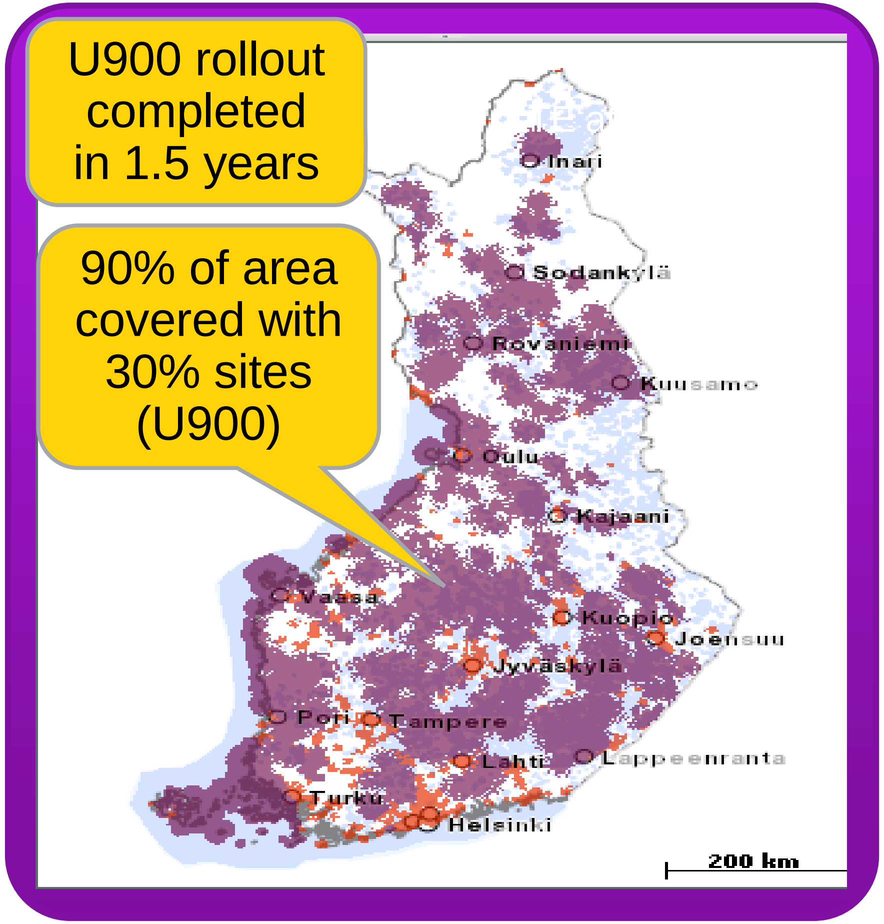
Source: Deutsche Telekom

- **Government regulation (USO):**
  -> specific rollout requirements within 800 MHz spectrum license
- Service provided outside wireline-DSL areas

Coverage – Low Band and FDD best for wide area WCDMA/HSPA – FDD 900MHz

- **Government regulation (USO):**
  -> provide access to 1 Mbps broadband for every household – either wireline or wireless
- Target date: July 1, 2010
- HSPA900 chosen in view of time-line and 800 MHz spectrum availability
- > 500 devices in all form-factors & price-points

Example: UMTS 900 Coverage (Finland)



= UMTS900

= UMTS2100

Source: TeliaSonera

TeliaSonera

3 – times more coverage on 900 MHz

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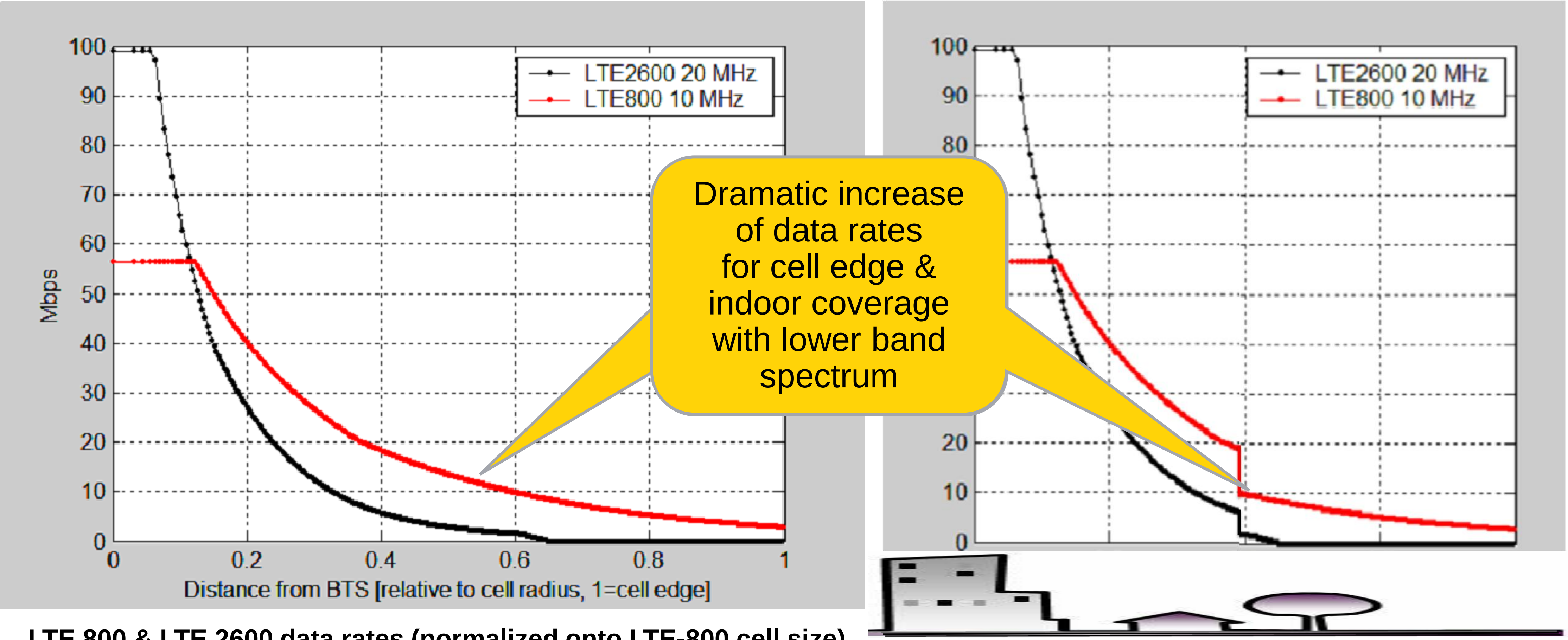
Coverage – Low Band and FDD
The power of 700/800/900 MHz for urban indoor coverage



LTE 800 & LTE 2600 data rates (normalized onto LTE-800 cell size)

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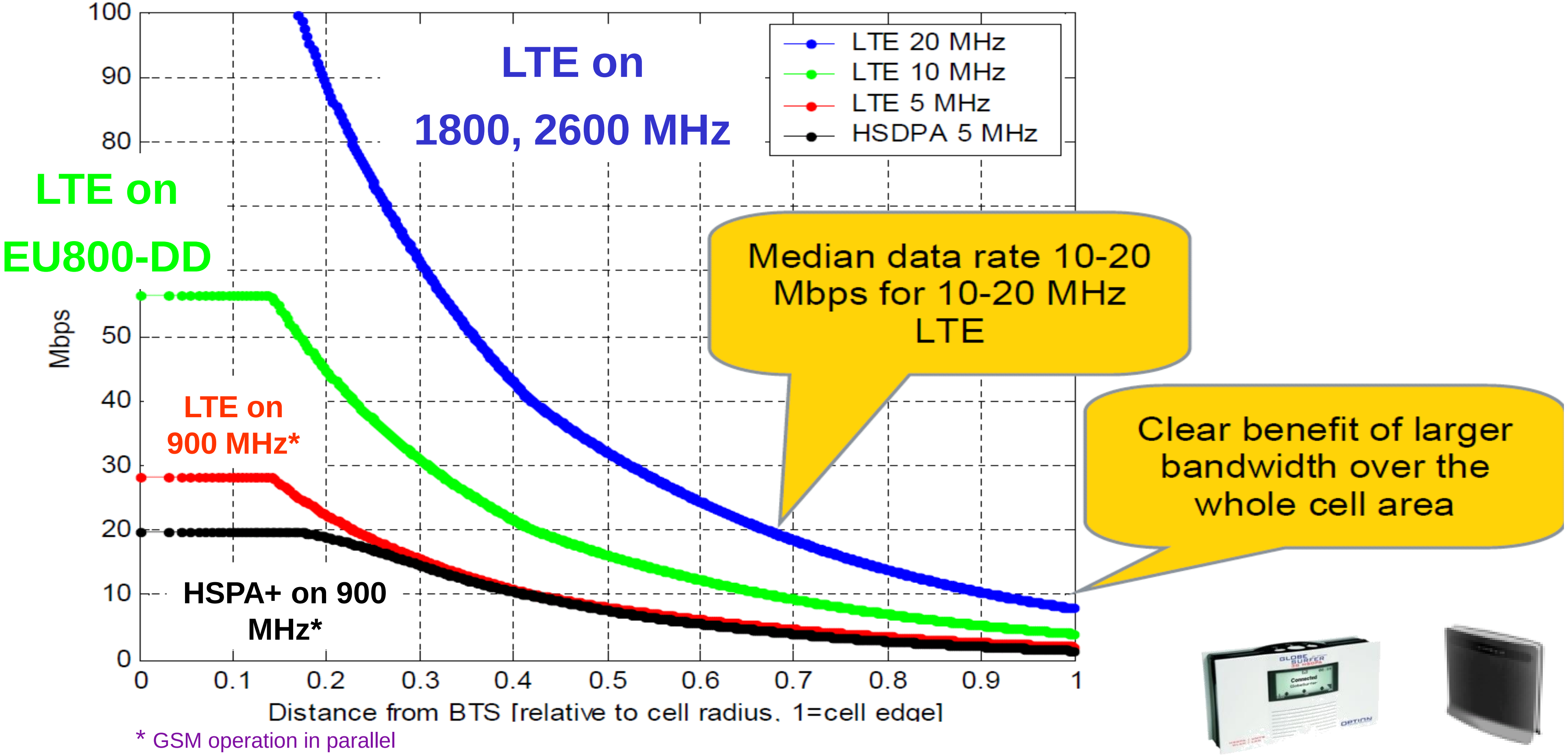
More bandwidth = Superior data rates across cell range

LTE Downlink Bit Rates
– Interference Limited, Other Cells 100% Loaded



* GSM operation in parallel

10 km

(indicative range for 30m antennas)

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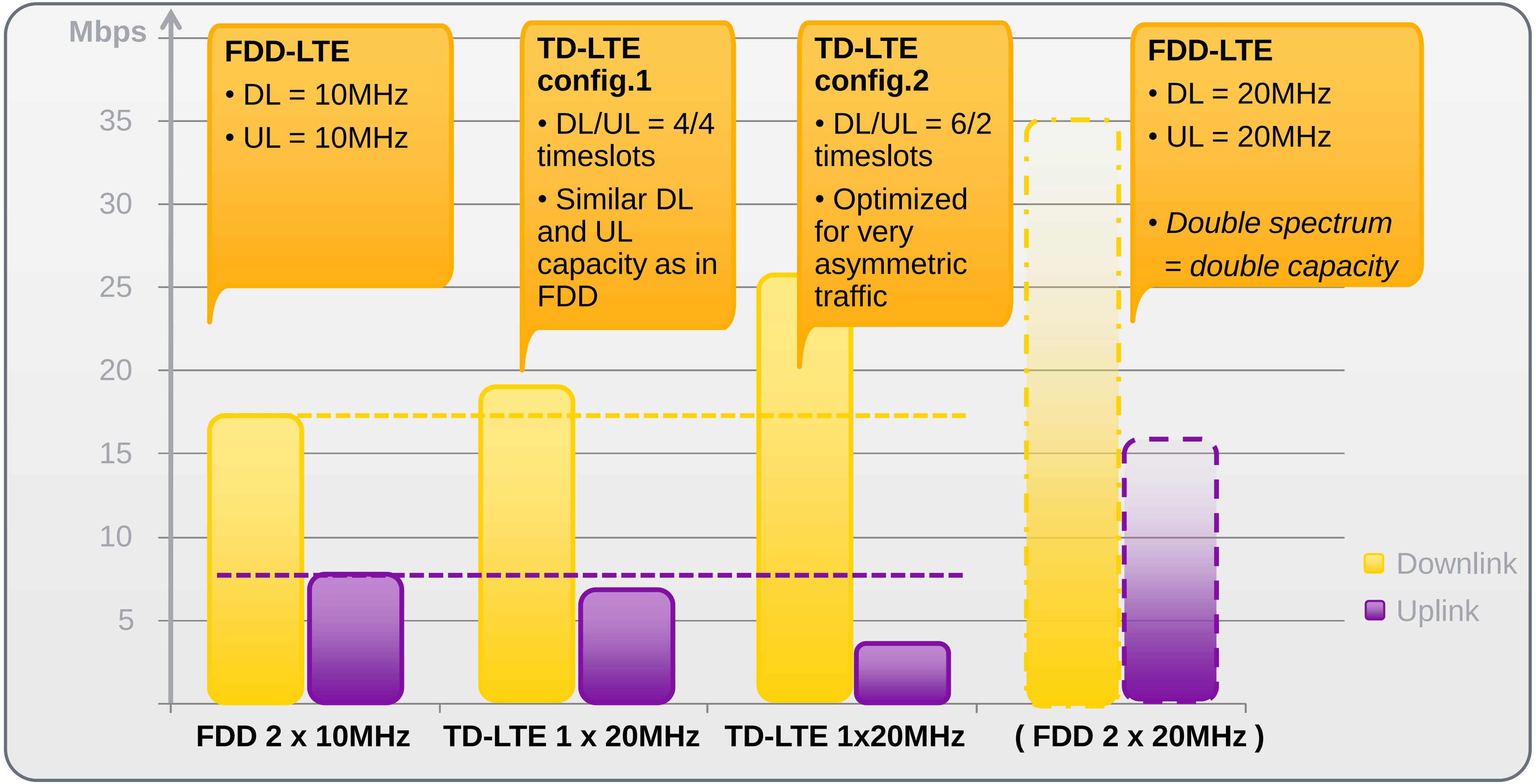
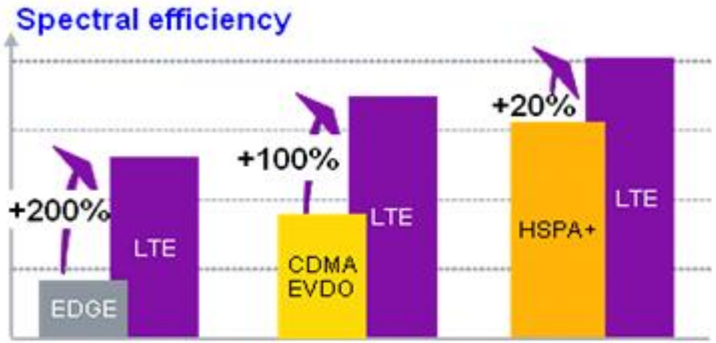
TD-LTE Capacity
Similar spectral efficiency for TD-LTE and LTE-FDD



Practical Data Rate Evolution – End-user experience



LTE improves data rates compared to HSPA

- **with *wider bandwidth*, and**
- **with *higher spectral efficiency* (20-40%)**

	Peak rates	Typical drive test rates	
HSPA+ 5 MHz	21 Mbps (42 Mbps)	7 Mbps	
DC-HSPA 10 MHz	42 Mbps (84 Mbps)	14 Mbps	DC-HSPA doubles data rates
LTE **10 MHz**	74 Mbps	**20 Mbps**	= 2 x more spectrum + 40% vs HSPA
LTE **20 MHz**	100 (150) Mbps	**40 Mbps**	= 4 x more spectrum + 40% vs HSPA

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Peak data rates
Driven by LTE terminal capabilities

All LTE devices which have been launched during 2010

	Class 1	Class 2	Class 3	Class 4	Class 5
Peak rate DL/UL	**10/5 Mbps**	**50/25 Mbps**	**100/50 Mbps**	**150/50 Mbps**	**300/75 Mbps**
RF bandwidth	20 MHz*	20 MHz*	20 MHz*	20 MHz*	20 MHz*
Modulation DL	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM
Modulation UL	16 QAM	16 QAM	16 QAM	16 QAM	64 QAM
Rx diversity	yes	yes	yes	yes	yes
MIMO DL	optional	2 x 2	2 x 2	2 x 2	4 x 4

* All 3GPP Rel.8 LTE terminals can receive 20 MHz bandwidth, but (baseband) processing power is variable

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Spectrum Resources – Europe

- Main LTE bands in **Europe:** ***800, 1800 and 2600 MHz***

Overall spectrum available		**Typical future CSP deployment scenario**	
2600 (2x70 MHz + 50 MHz)	*new spectrum*	LTE 20 MHz TD-LTE 20 MHz	**LTE capacity & highest data rates**
2100 (2 x 60 MHz)	*WCDMA/HSPA*	Multicarrier HSPA	*HSPA capacity*
1800 (2 x 75 MHz)	*GSM*	LTE 10+MHz & GSM (defragmentation)	**LTE capacity +** *GSM capacity*
900 (2 x 35 MHz)	*GSM*	HSPA 5+MHz & GSM (defragmentation)	*HSPA coverage + GSM maintenance*
EU800 (2 x 30 MHz)	*new spectrum, Digital Dividend / TV-transition*	LTE 10 MHz	**LTE coverage**

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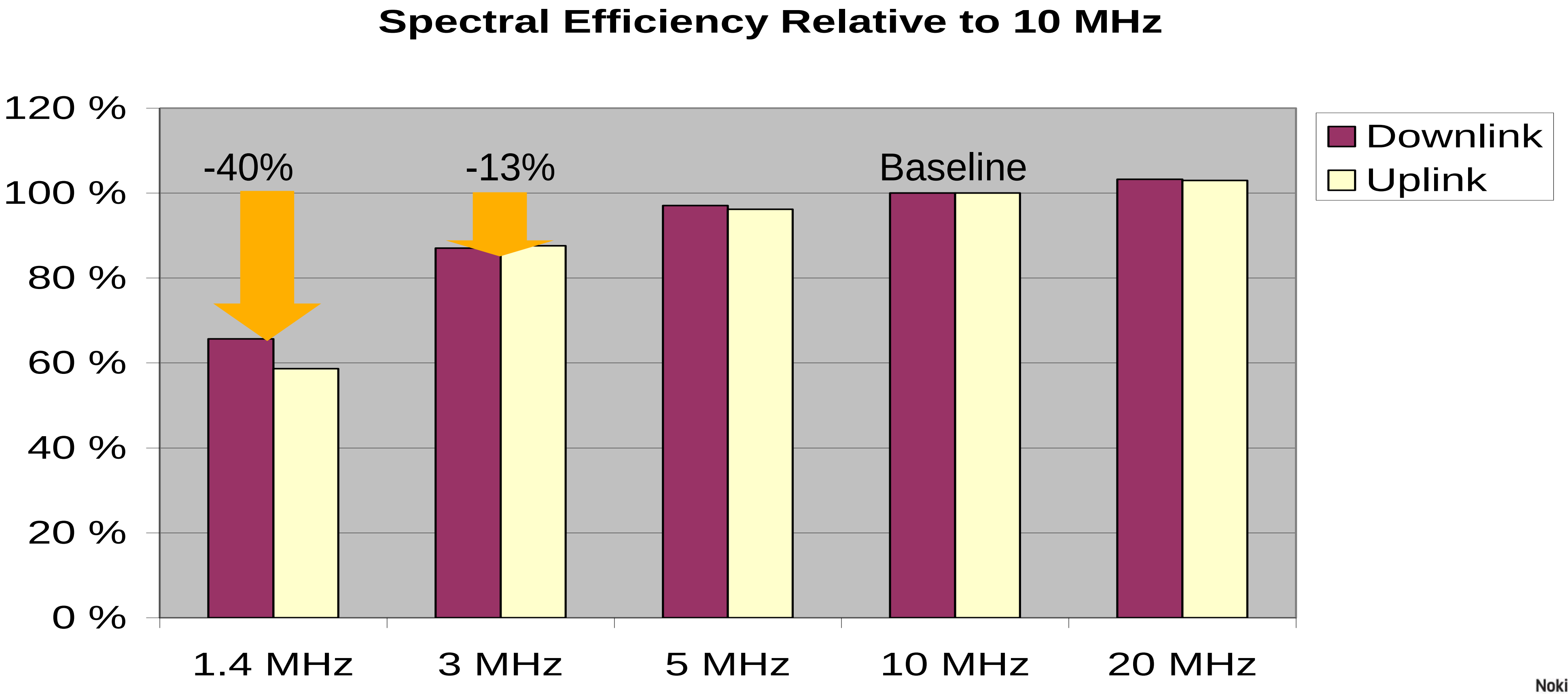
Capacity - Highest spectral efficiency with LTE
LTE maintains highest efficiency down to 5 MHz bandwidth

LTE maintains high efficiency with bandwidth down to 3.0 MHz, e.g. for band refarming scenarios

LTE spectral efficiency for 1.4 MHz similar to HSPA with 2x2 MIMO and 64-QAM

Differences between bandwidths come from frequency scheduling gain and different overheads



Agenda

MOBILE BROADBAND

- Introduction
- WCDMA/HSPA/HSPA+
- **LTE**
  - Introduction
  - LTE Spectrum
  - **Radio Access Overview**
  - Core Network Overview
  - Voice over LTE (VoLTE)
  - QoS in LTE
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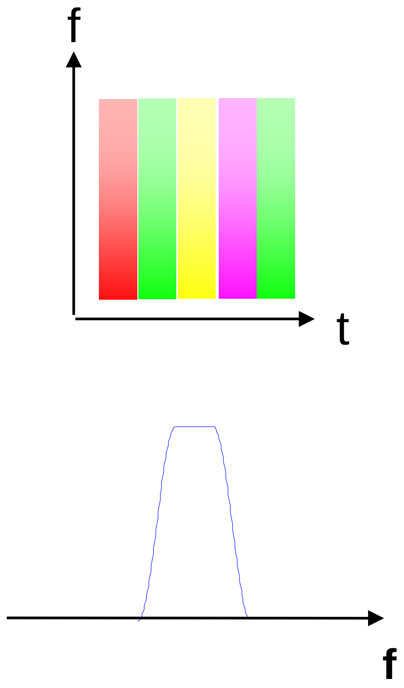
Multiple Access Methods

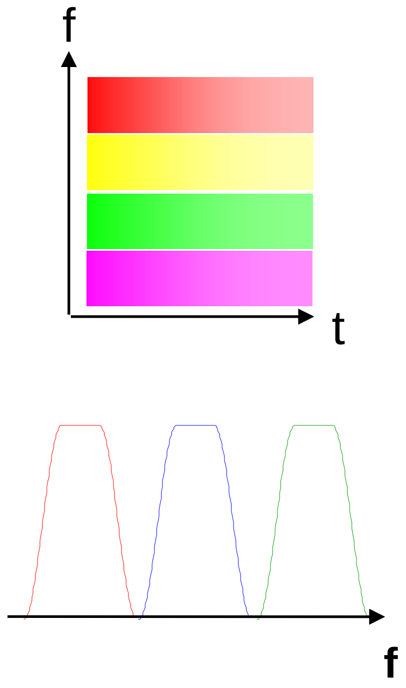
TDMA

- Time Division



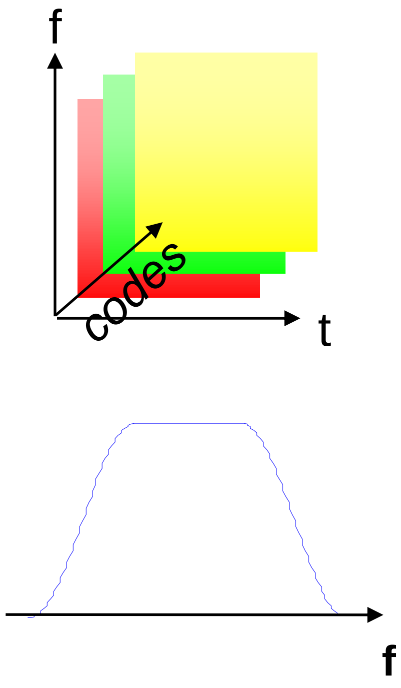
FDMA

- Frequency Division



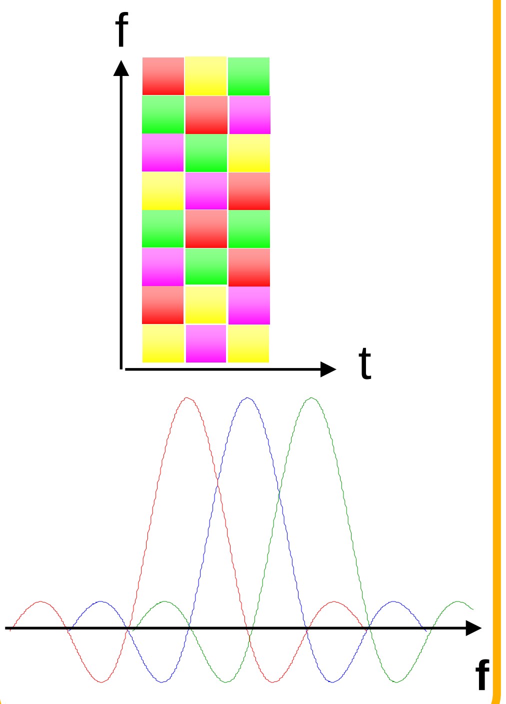
CDMA

- Code Division



OFDMA

- Frequency Division
- Orthogonal subcarriers



User 1 User 2 User 3 User ..

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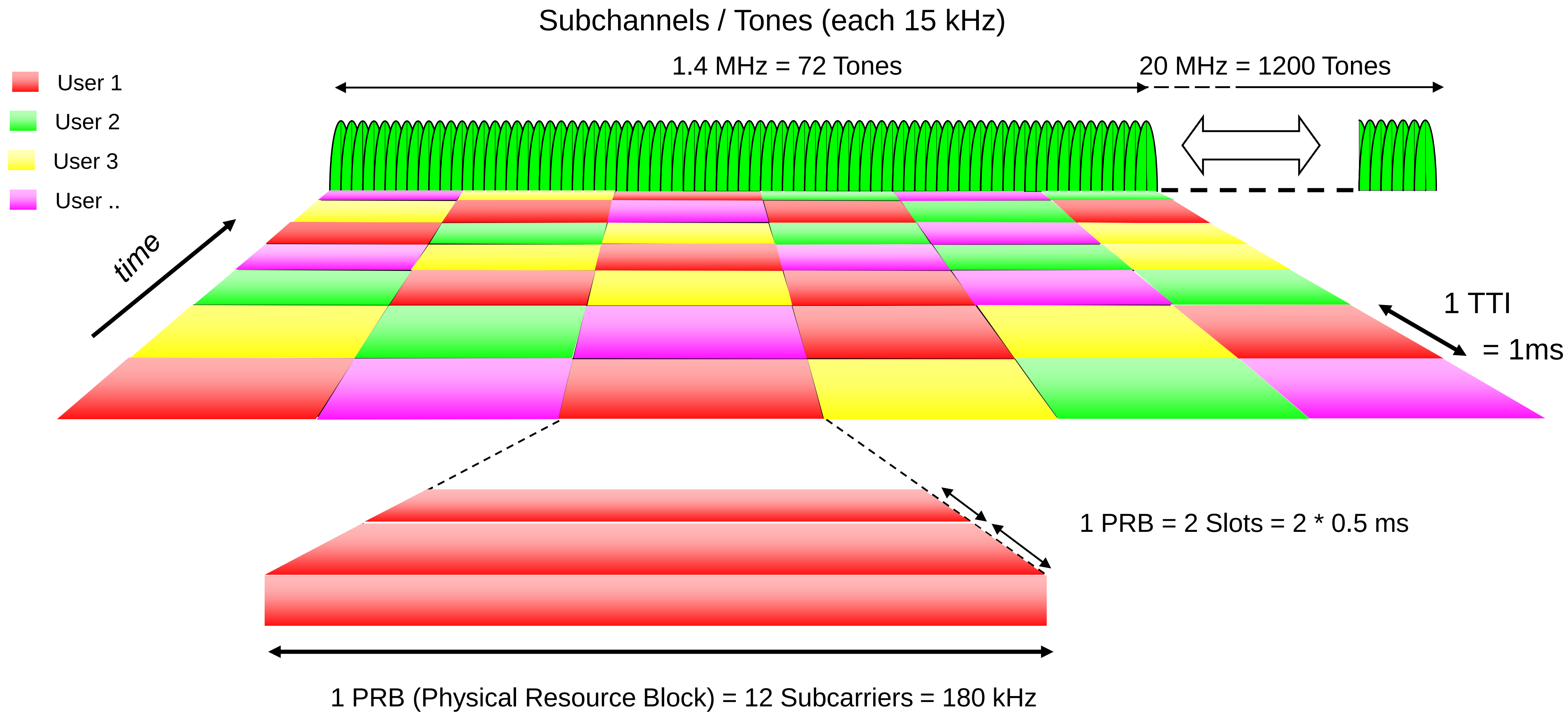
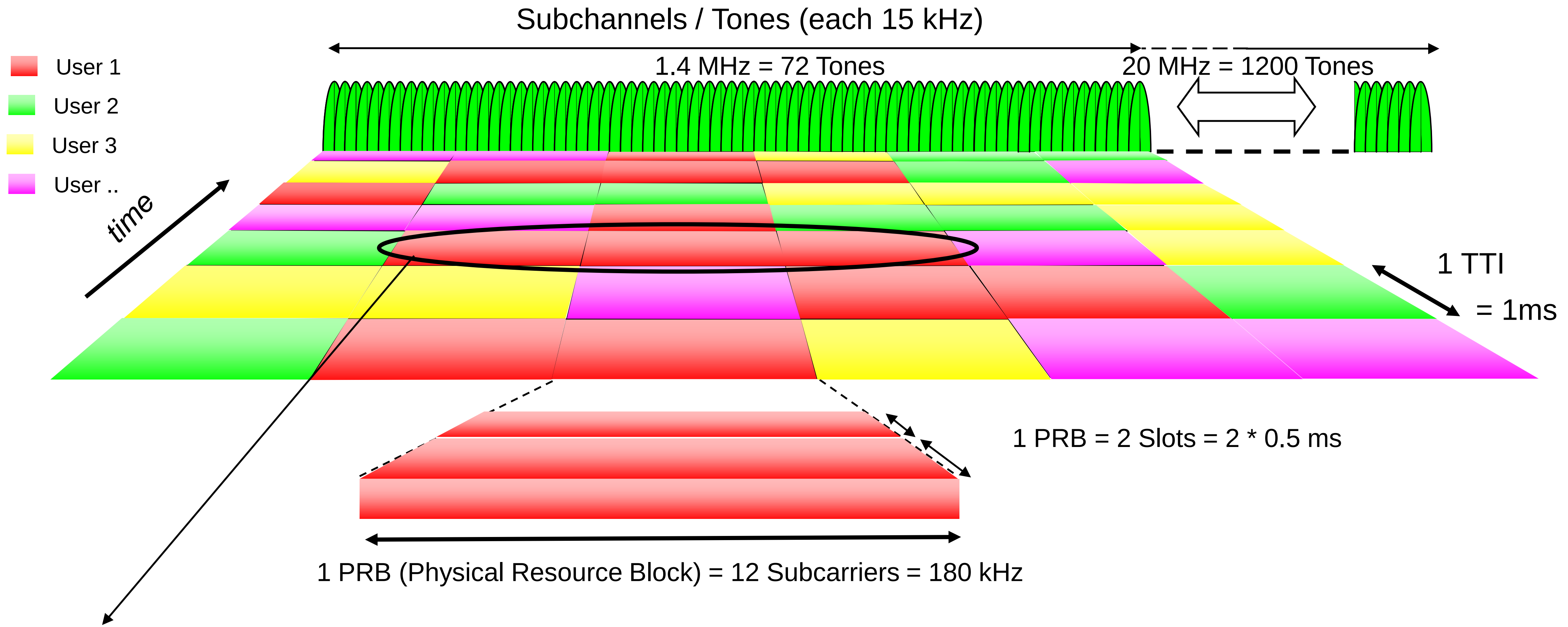
Downlink - OFDM



Uplink – Single Carrier FDMA



SC-FDMA: PRB‘s are grouped to bring down Peak to Average Power Ratio (PAPR)
→ better power efficiency at the terminal

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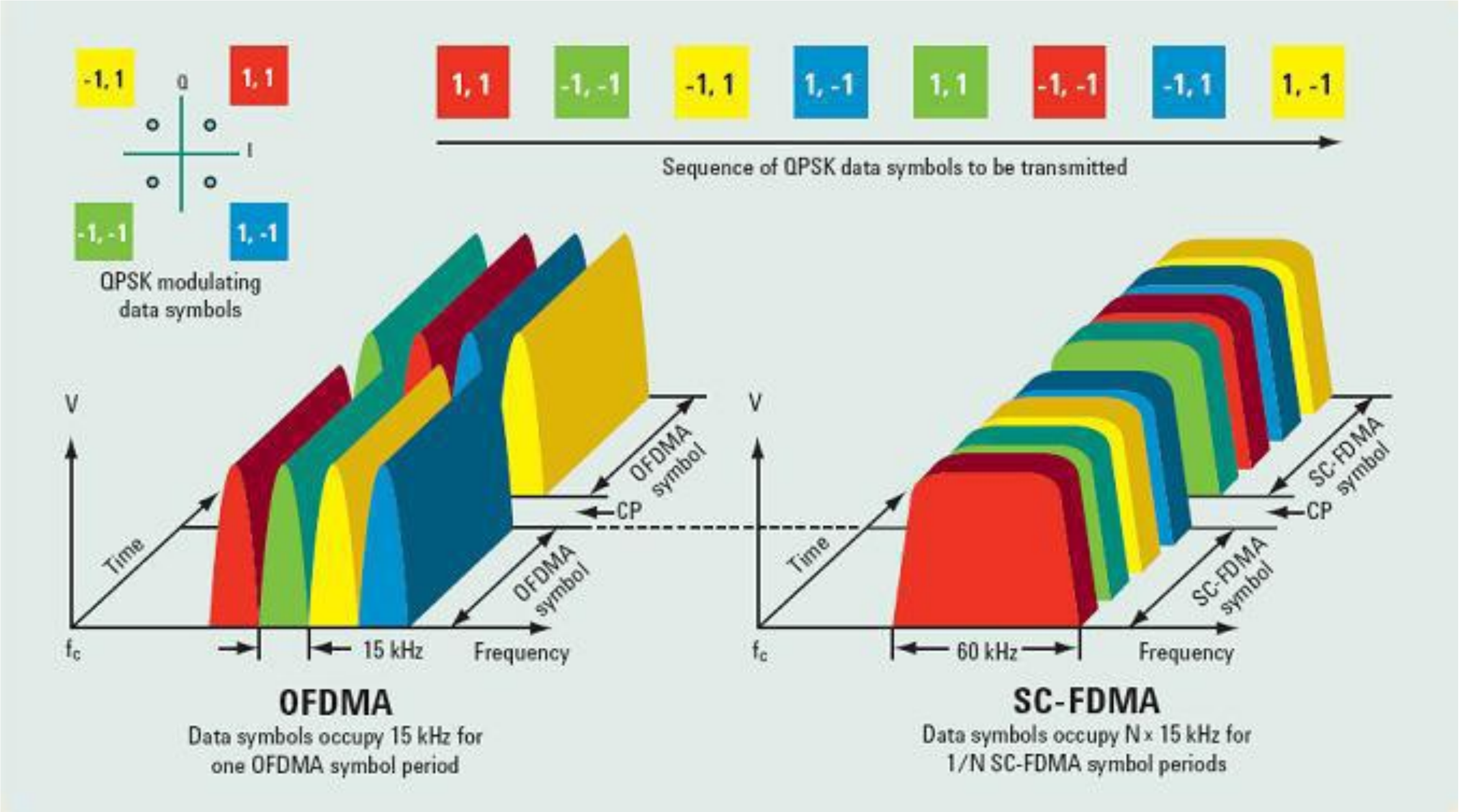
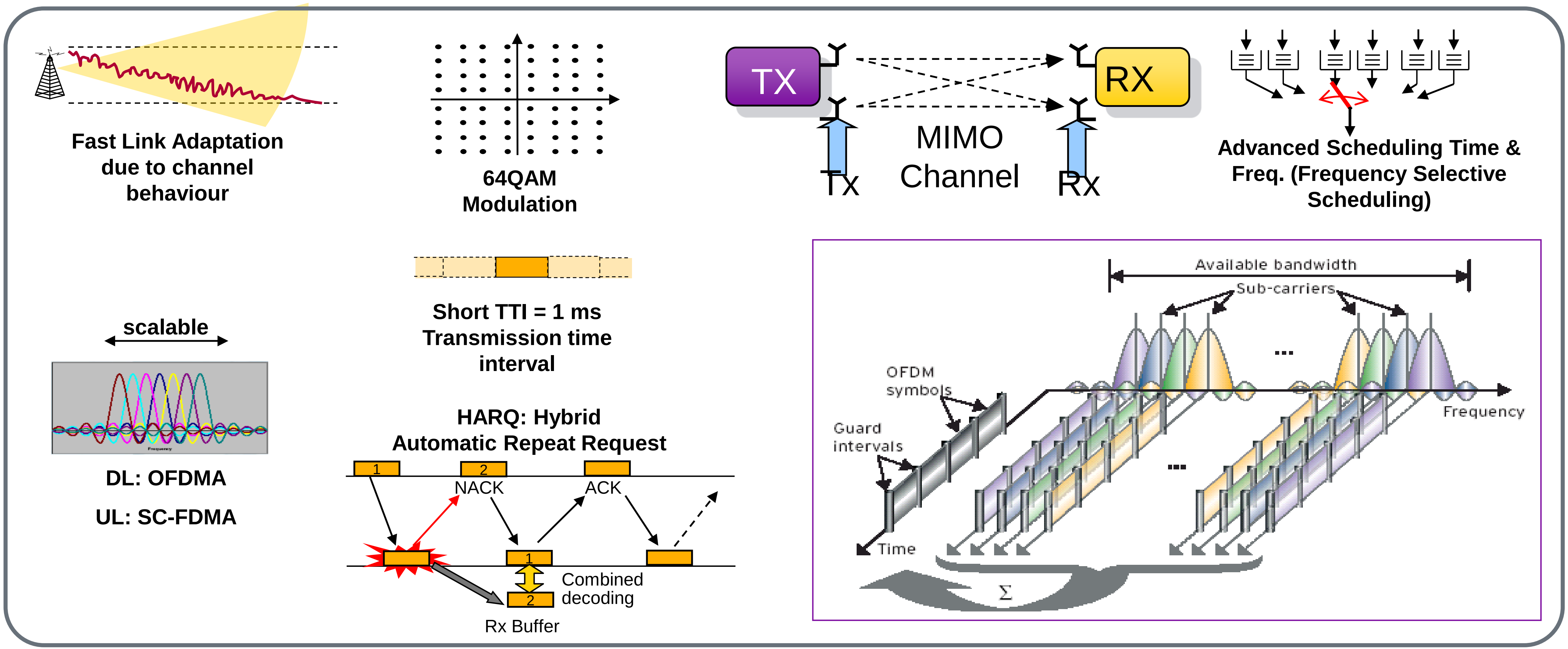
OFDMA vs SC-FDMA

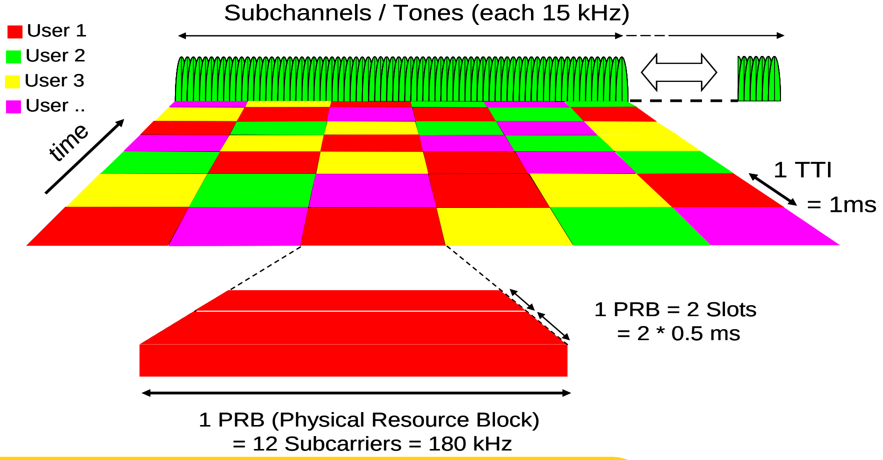


LTE Radio highlight



LTE: Most efficient Radio Access Technology

LTE Radio principles



Downlink:

OFDMA

- Improved spectral efficiency
- Reduced interference
- Very well suited for MIMO

Uplink:

SC-FDMA

- Power efficient uplink increasing battery lifetime
- Improved cell edge performance by low peak to average ratio
- Reduced Terminal complexity

- Enabling peak cell data rates of 173 Mbps DL and 58 Mbps in UL *
- Scalable bandwidth: 1.4 / 3 / 5 / 10 /15 / 20 MHz also allows deployment in lower frequency bands (rural coverage, refarming)
- Short latency: 10 – 20 ms **

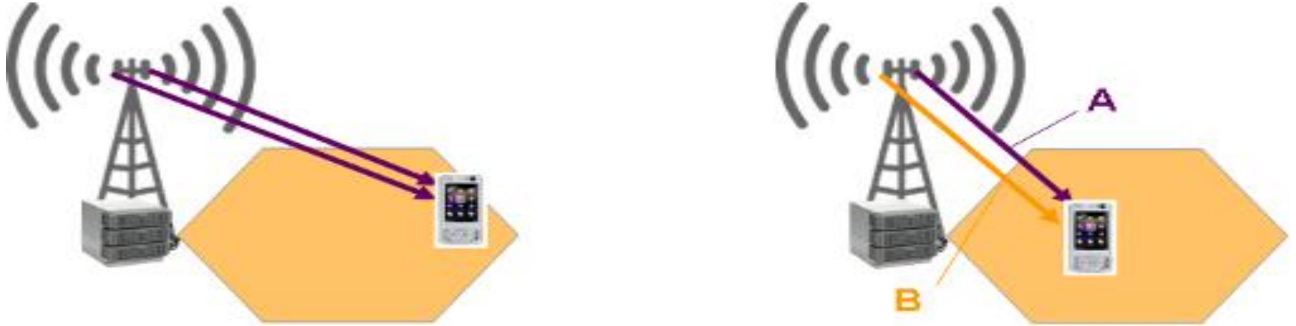
* At 20 MHz bandwidth, FDD, 2 Tx, 2 Rx, DL MIMO, PHY layer gross bit rate

** roundtrip ping delay (server near RAN)

MIMO Technology Overview

Several antenna technologies are summarized under the term MIMO (Multiple Input / Multiple output):

- Single user DL MIMO
  - DL MIMO - transmit diversity
  - DL MIMO - spatial Multiplexing



- Multi-user MIMO

- Virtual MIMO (UL MIMO)

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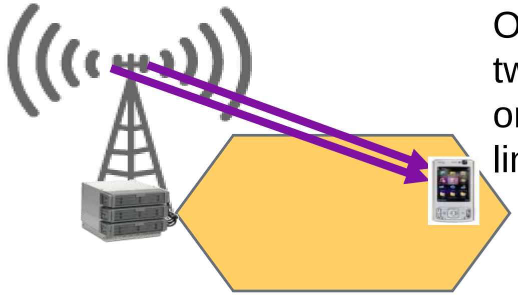
DL single user MIMO – with 2 antennas

DL MIMO – Transmit diversity

➢**Enhanced cell edge performance, capacity increase**

- 2 TX antennas
- Single stream (code word)

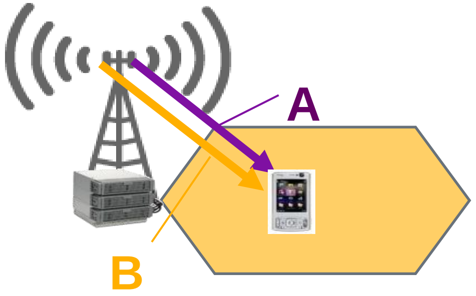


One code word A is transmitted via two antennas on the same PRB to one far away UE which improves the link budget / SNIR.

DL MIMO – Spatial multiplexing

➢**Doubles the peak rate at good channel quality (near BTS)**

- 2 TX antennas
- Spatial multiplexing with two code words



Two code words (A+B) are transmitted in parallel on the same PRB to one UE which doubles the peak rate.

Optimum solution: Dynamic selection between

- Spatial multiplexing with two code words (UE near the BTS)
- Transmit diversity with one code word (UE far away from BTS to improve link budget / SNIR)

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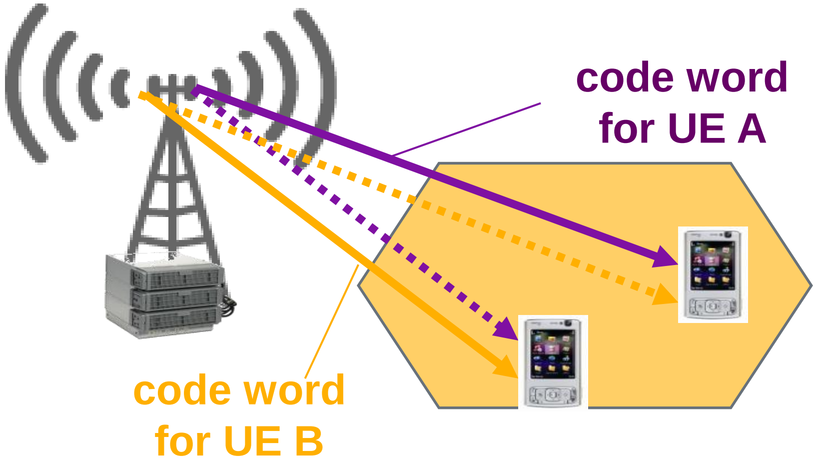
DL multi user MIMO

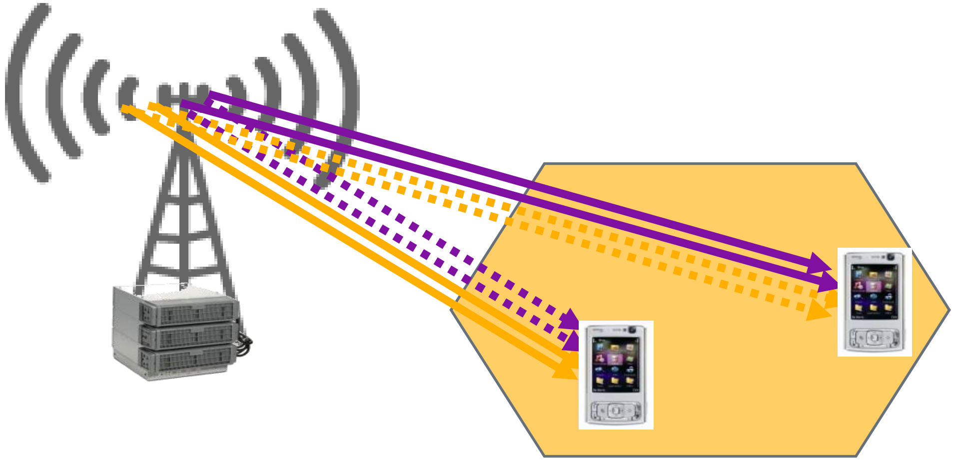
With 2 antennas

- Higher number of simultaneous users
- Dynamic selection of a pair of UEs using the same PRBs
- One stream has user data meant for particular UE
- Second stream meant for other UE, ignored by particular UE

With 4 antennas

- Improved coverage when compared to 2 Tx Antenna case
- 2 user data streams for particular UE (redundancy)
- Other 2 streams meant for other UE, ignored by particular UE
- 2 code words only (4 code words not standardized)



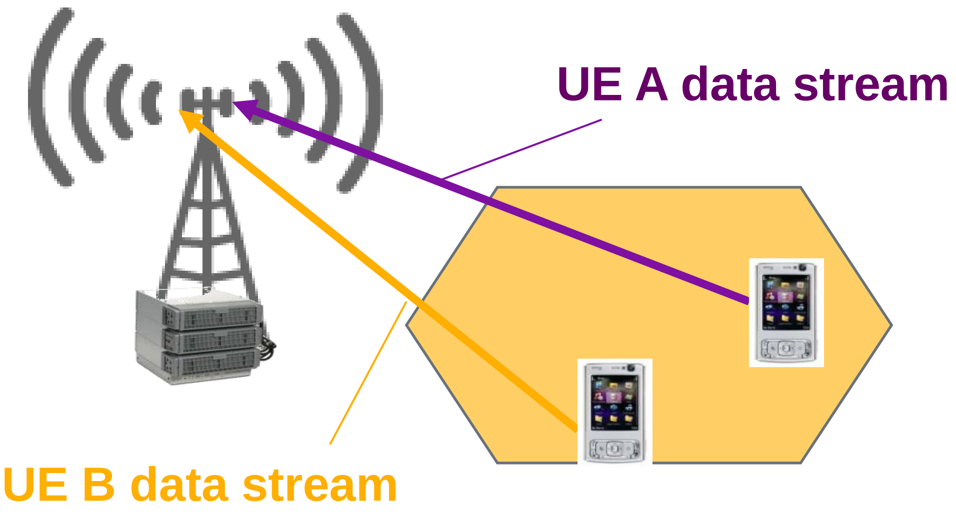


Multi – User MIMO potentially not in Rel 8 standards
Gains relatively small (<10% at fully loaded network)

UL multi user MIMO (virtual MIMO)

- In uplink, multi-stream transmission from single UE is not supported.
  - single Tx antenna and power amplifier at UE
- So-called virtual MIMO or UL MU-MIMO is used instead
  - Two users are scheduled to use the same resource so the base station receives multi-stream transmission on the same PRB

➔ Increased UL cell throughput by multi user diversity gains



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E-UTRAN Node B (eNodeB)

- eNodeB is the only node that controls all radio related functions:

  - Acts as layer 2 bridge between UE and EPC
    - Termination point of all radio protocols towards UE
    - Relaying data between radio connection and corresponding IP connectivity towards EPC
  - Performs ciphering/deciphering of the UP data and IP header compression/decompression
  - Responsible for **Radio Resource Management** (RRM)-
    - allocating resources based on requests
    - prioritizing and scheduling traffic according to required Quality of Service (QoS).
  - **Mobility Management-**
    - controls and analyses radio signal level measurements by UE, makes similar measurement itself and based on those makes HO decision.

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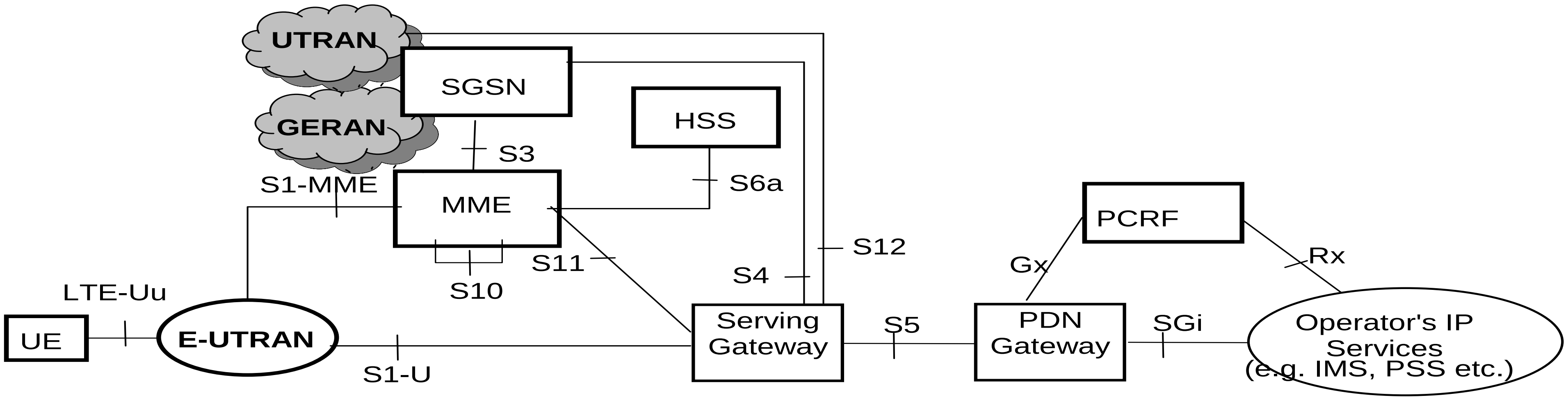
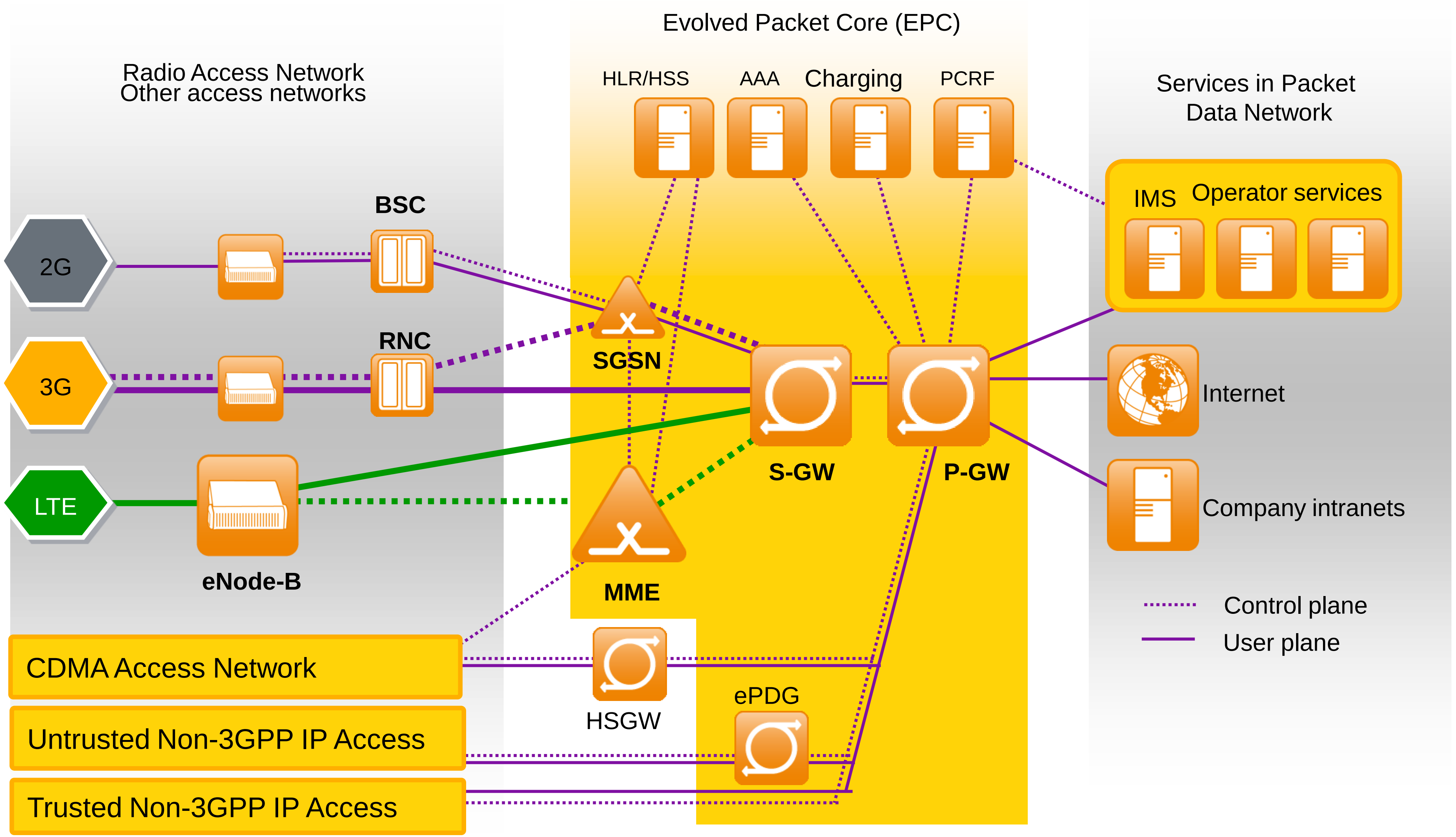
Main EPS Standards: 23.401

- Defines EPS architectures for 3GPP accesses using GTP protocol (GTP on S5/S8)
  - One example is given below
- Defines role of MME, SGW and PGW
- Two GW configurations: standalone SGW and PGW, co-located SGW/PGW
- Defines high level procedures (mobility management, session management, interworking with existing accesses, etc.)



Non-roaming architecture for 3GPP accesses

3GPP R8 Architecture:
Flat architecture for high efficiency



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Core Technology Overview

Mobility Management Entity

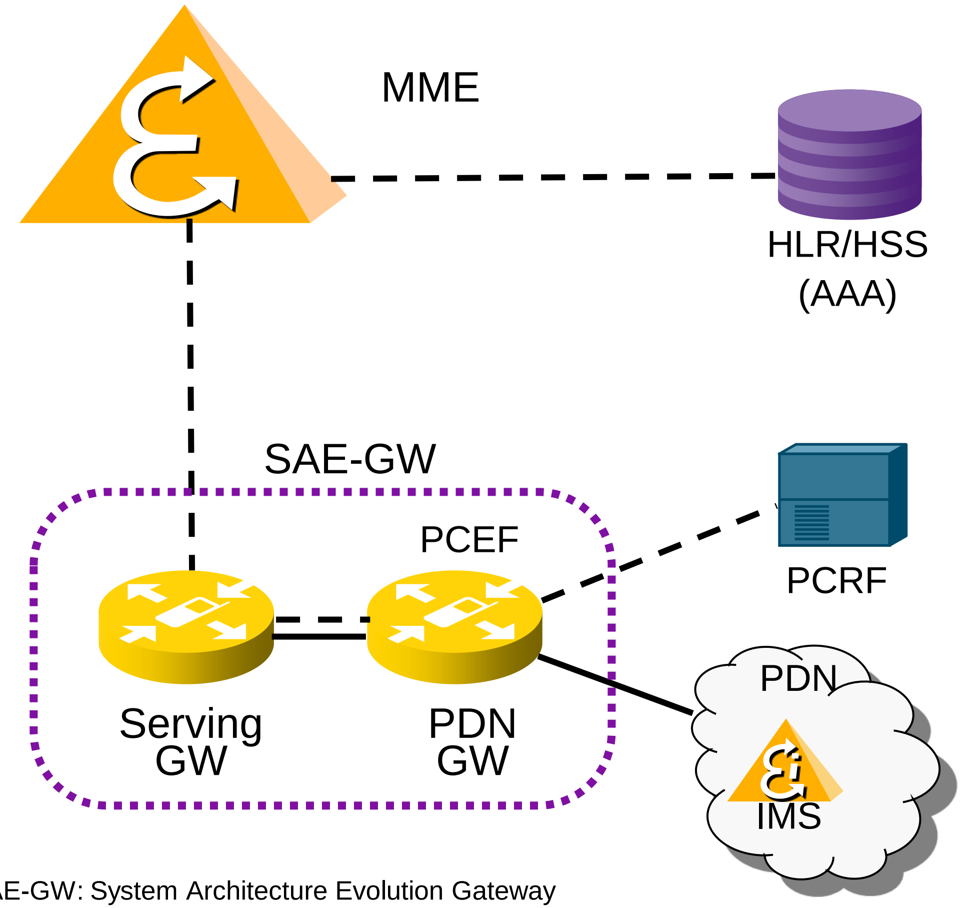
- C-Plane Part
- Session & Mobility management
- Idle mode mobility management
- Paging
- AAA Proxy

Serving Gateway

- User plane anchor for mobility between the 2G/3G access system and the LTE access system.
- Resides in visited network in roaming cases
- Lawful Interception

Packet Data Network Gateway

- Gateway towards Internet/Intranets
- User plane anchor for mobility between 3GPP and non-3GPP access systems (HA).
- Charging Support
- Policy and Charging Enforcement (PCEF) *)
- Packet Filtering
- Lawful Interception



SAE-GW: System Architecture Evolution Gateway
= S-GW + PDN-GW

*) PCRF: Policy and Charging Rules Function communicates with PCEF (Policy and Charging Enforcement Function within PDN SAE GW)

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Reasons for VoLTE - simultaneous voice and data

Spectral efficiency

"More bang for the MHz and buck", 2x more voice calls at reduced cost

Voice quality

HD voice, GBR QoS, short call setup time

Simplification

Voice becomes data and runs in the same all IP environment

Richer voice

A multimedia environment enriches voice and equips for OTT fight

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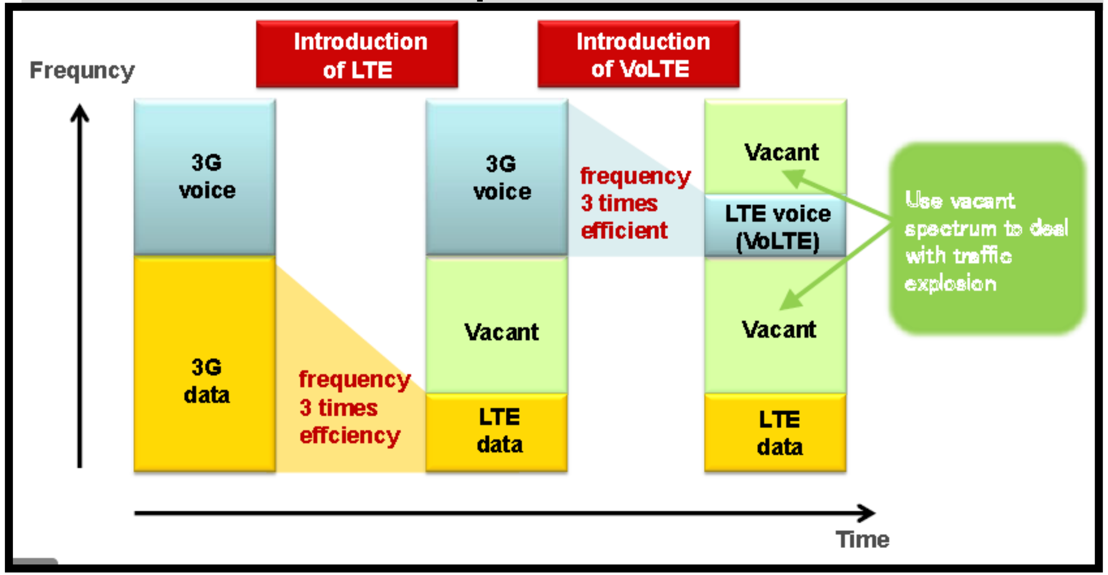
Why VoLTE – Operator view (DoCoMo)

Benefit for the operator



- Benefits for customers
  - Faster call set-up
  - Mobile broadband still available during voice call
  - Service quality better than OTT VoIP apps
    - Priority handling, SRVCC
  - Existing supplementary services are supported

Our philosophy behind: Maintain the same service quality as the existing 3G voice service to satisfy customer needs.

Comparison vs. OTT VoIP

Services	VoLTE	OTT VoIP Apps	
Use of E.164 Number	✓	Limited	Limited to certain numbers/operators
Emergency Call	✓	✗	
CLIP/CLIR	✓	✗	Originating number not always displayed
Priority Calls	✓	✗	
Voice mails	✓	✓	Supported by certain app e.g. Skype
Call Diversion	✓	✓	
Other supplementary services	✓	✗	

… however, DoCoMo has not launched VoLTE yet.

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Example from an early VoLTE Launch: SKT Telecom

VoLTE service provides higher quality of Voice and will be mashed up with other rich IP services such as RCS for better communication user experience

Fact box:

Launch: 8 Aug 2012
Brand name: HD Voice
Price: Same as 3G
Phone: Samsung Galaxy S3 LTE
Service: Initially VoLTE<-> VoLTE, later to CS and PSTN, SRVCC

SKT VoLTE - HD Voice

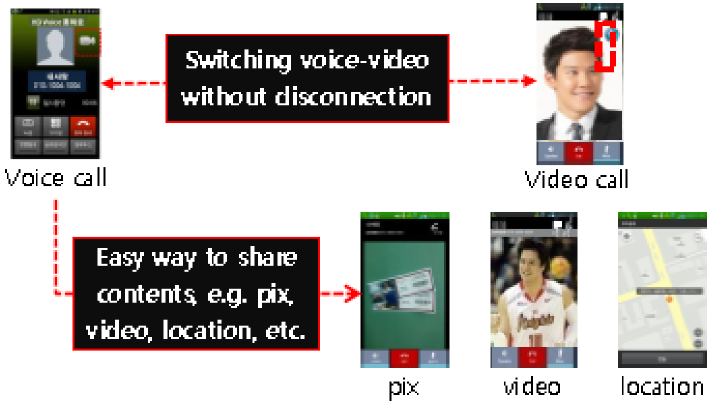
- High-definition quality of voice and short call set-up time

	HD Voice	3G Voice
Bandwidth	50~7000Hz (2.2 times↑)	300~3,400Hz
Voice Codec	12.65 ~ 23.85Kbps (Max 2 times ↑)	12.2Kbps
Call Set-up Time	0.25~2.5 Secs (Max 20 times↑)	Avg. 5 Secs
Value Added Service	Voice and data integrated rich communication	Voice and video provided separately
Stability	High (Packet-base, QCI*)	High (Circuit-base)

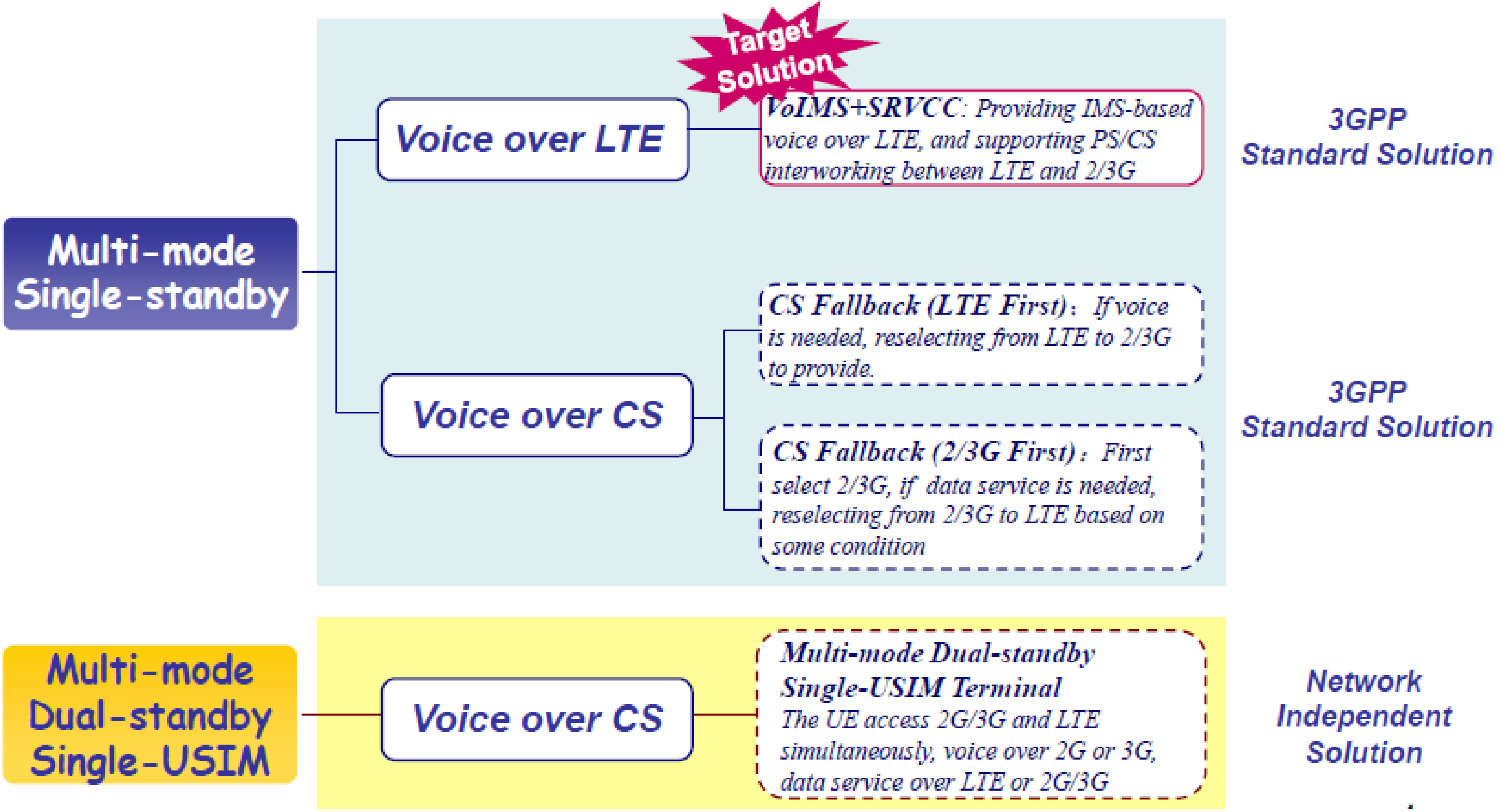
※ QCI: QoS Class Identifier; guarantee stability by dealing with VoLTE the first priority

Key Features

- Easy switch between voice call, video call and contents sharing



Alternative of LTE voice solution

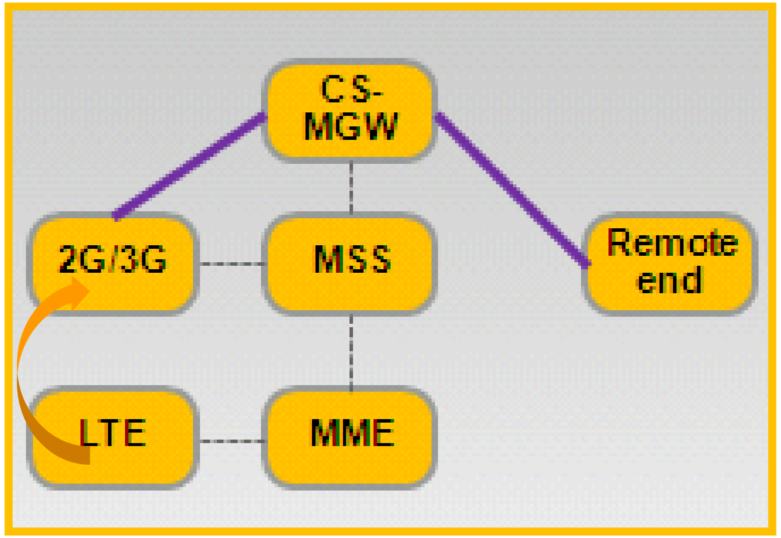


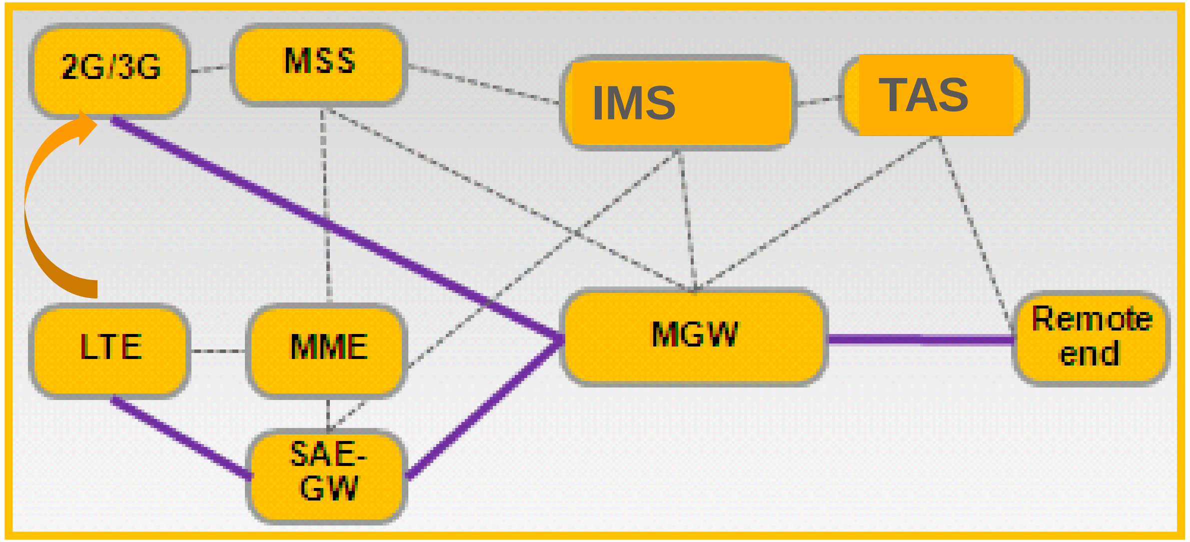
Potential voice evolution steps in LTE

- LTE used for high speed packet data access only
  - Operator voice service provided over CS network
- Fallback to CS voice
  - LTE network is used for data only
  - Terminal is simultaneously registered to both LTE and 2G/3G CS network
  - Voice calls are initiated and received over CS network
- Single radio Voice Call Continuity (VCC)
  - Operator provides VoIP over LTE
  - IMS acts as control machinery
  - Voice calls can be handed over to CS network
- All-IP network
  - Operator provides VoIP over LTE
  - IMS acts as control machinery
  - Voice calls can be handed over to other packet switched networks

The transition to VoLTE technology

CSFB → SRVCC VoLTE





- Fallback to 2G/3G/CDMA access for voice
- LTE SMS
- MSC Server / MSC for voice

- Voice over LTE
- IMS for voice and Telecom Application Server for voice
- Rich Communication Services

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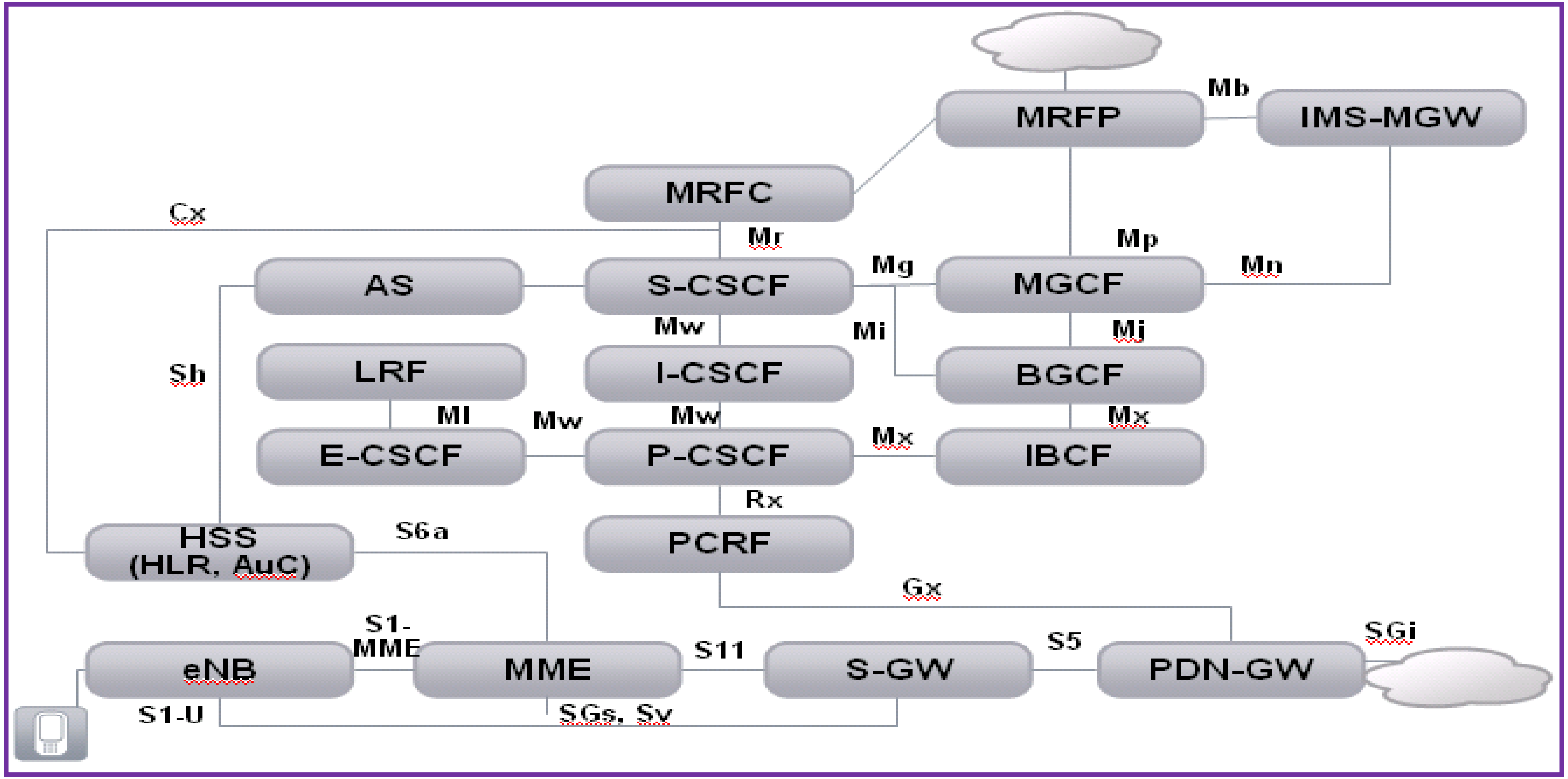
3GPP reference architecture



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VoLTE Standardization Status

3GPP A GLOBAL INITIATIVE

R5-R7
- IMS introduced

Rel-8
- LTE introduced
- SRVCC defined

Rel-9
- SRVCC supporting mid-call
- VoLTE emergency call

Rel-10
- SRVCC enhancement

Rel-11 (ongoing)
- rSRVCC
- vSRVCC
- VoLTE roaming architecture

GSMA

VoLTE basic requirements
- IR.92 defines VoLTE profile

VoLTE international roaming & interworking
- Requirements for VoLTE roaming architecture
- VoLTE roaming architecture
- IR.65 defines principles for IMS roaming & interworking
- IR.88 defines LTE roaming architecture for VoLTE

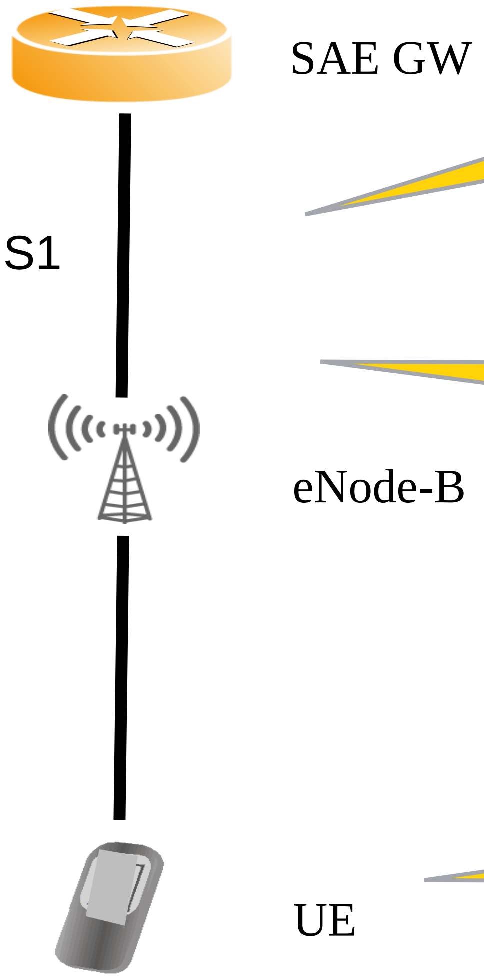
VoLTE futher requirements
- IR.64 IMS Service Centralization and Continuity Guidelines

Nokia Siemens Networks

Agenda

- Introduction
- WCDMA/HSPA/HSPA+
- **LTE**
  - Introduction
  - LTE Spectrum
  - Radio Access Overview
  - Core Network Overview
  - Voice over LTE (VoLTE)
  - **QoS in LTE**
  - Self Organizing Network (SON)
- LTE-Advanced
- Summary

LTE QoS Overview

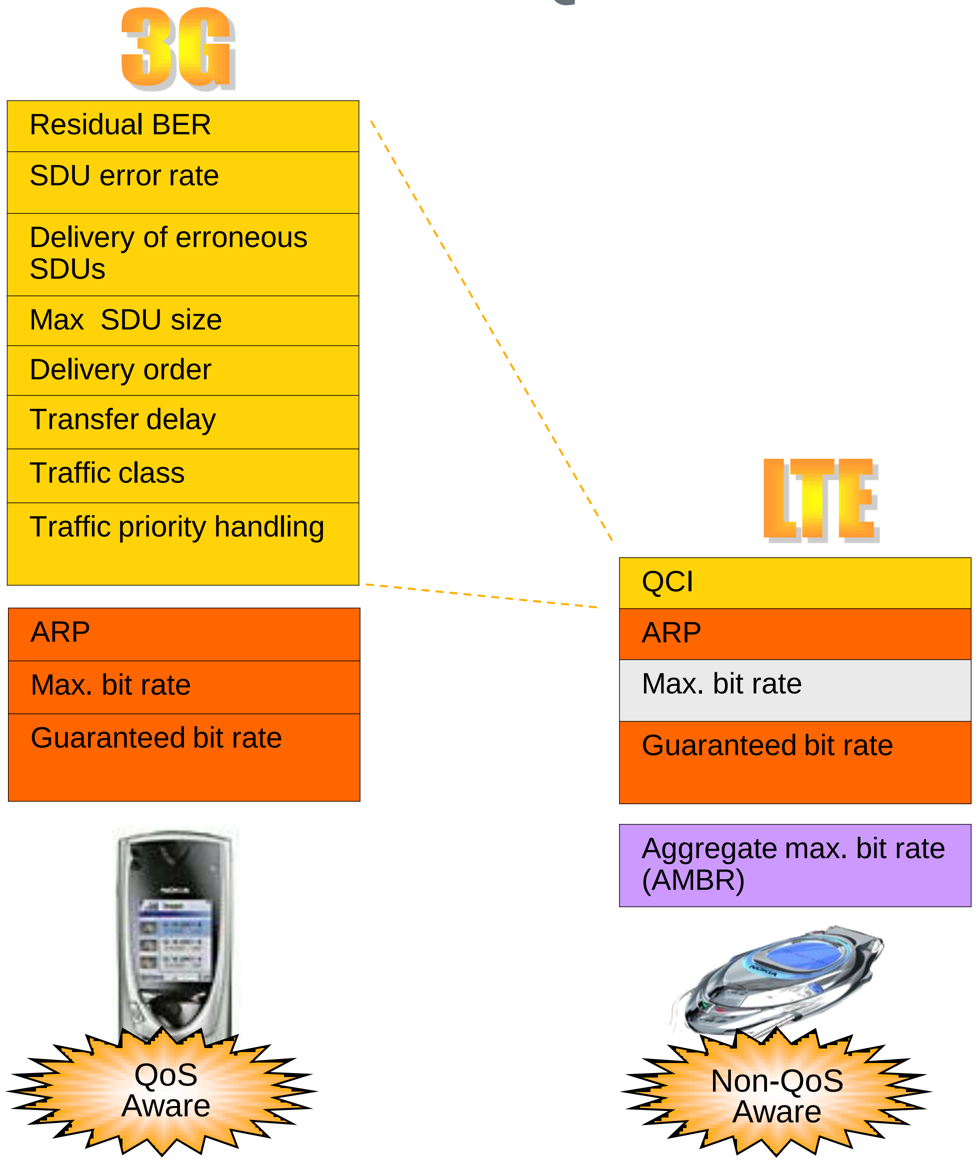


- QoS parameters in open S1 interface are standardized
- QoS is bearer based – not packet based
- QoS algorithms in radio network are not standardized

Similar to 3G

- Full network control without UE QoS requirements

Network-centric QoS scheme



Substantially optimized Bearer handling compared to 3G networks

Single scalar label (QCI) is a pointer to a set of QoS parameters

Network-centric QoS scheme reduces complexity of UE implementations

- Always on default EPS bearer available after initial access
- Further dedicated EPS bearer setup on network request
(e.g. for VoIP calls)
- Does not require support from terminal application clients or device operating system

QCI... QoS control identifier
ARP… Allocation/Retention priority

QoS Class Indentifier (QCI) Table in 3GPP 23.203

QCI	Guarantee	Priority	Delay budget	Loss rate	Application
1	GBR	2	100 ms	1e-2	VoIP
2	GBR	4	150 ms	1e-3	Video call
3	GBR	5	300 ms	1e-6	Streaming
4	GBR	3	50 ms	1e-3	Real time gaming
5	Non-GBR	1	100 ms	1e-6	IMS signalling
6	Non-GBR	7	100 ms	1e-3	Interactive gaming
7	Non-GBR	6	300 ms	1e-6	TCP protocols : browsing, email, file download
8	Non-GBR	8	300 ms	1e-6	
9	Non-GBR	9	300 ms	1e-6	

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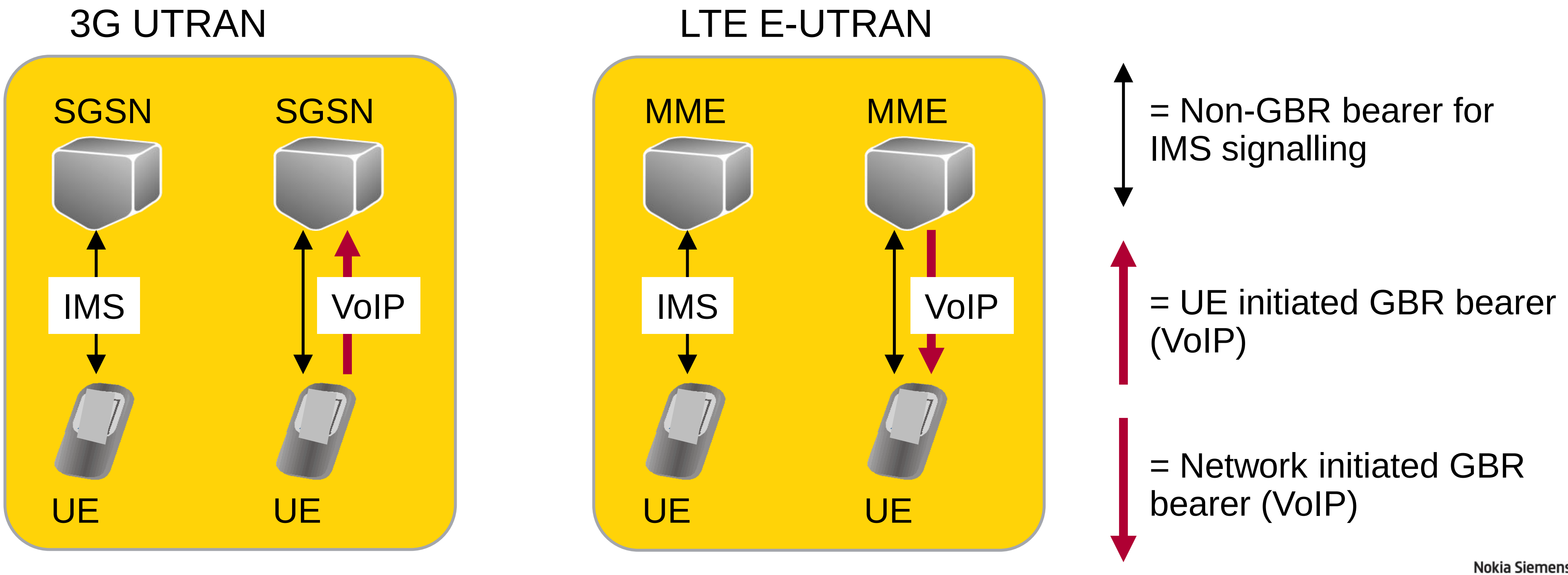
Mapping of 3G and LTE QoS Parameters

LTE	UMTS QoS			
QCI	Traffic class	Traffic handling priority	Signalling indication	Source statistic descriptor
1	Conversational	-	-	Speech
2	Conversational	-	-	Unknown
3	Streaming	-	-	Speech
4	Streaming	-	-	Unknown
5	Interactive	1	Yes	-
6	Interactive	1	-	-
7	Interactive	2	-	-
8	Interactive	3	-	-
9	Background	-	-	-

Network Initiated Bearer in LTE

- Guaranteed bit rate QoS requires its own bearer
- New bearer must be initiated by UE in 3G
- New bearer can be initiated by network in LTE ⇒ less requirements for the terminal and better network control



Nokia Siemens Networks

Agenda

- Introduction
- WCDMA/HSPA/HSPA+
- **LTE**
  - Introduction
  - LTE Spectrum
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  - Core Network Overview
  - Voice over LTE (VoLTE)
  - QoS in LTE
  - **Self Organizing Network (SON)**
- LTE-Advanced
- Summary

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What is SON?

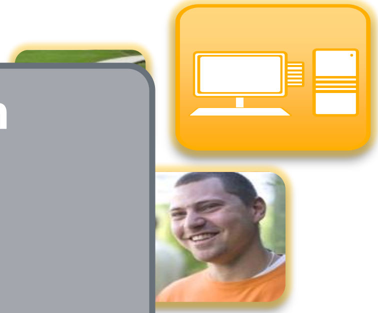
- SON originally refers to a network that can organize itself in the form of
  - **Self-Configuration**, e.g. initial parameter deployment,…
  - **Self-Optimization**, e.g. tuning the handover thresholds, …
  - **Self-Healing**, e.g. recovering from eNB failures automatically,…
- This is implemented as closely network related automation by
  - **Centralized SON:** associated with slow update rate and based on long term statistics where many cells are involved in optimization process. Implemented using network/element management system (OAM).
  - **Distributed SON:** require fast reaction time which affect only few cells, parameters have only local impact but configuration or status about neighbour cells are required. Optimization algorithms are implemented in eNodeB
  - **Localized SON:** require fast reaction time and only single cell involved- no impact on neighbour cells. Implemented by Radio Resource Management (RRM) in eNodeB
  - **Hybrid SON:** all the above 3 processes are used simultaneously for different use cases.

- SON can be considered as a specific type of automation

Why SON has been developed

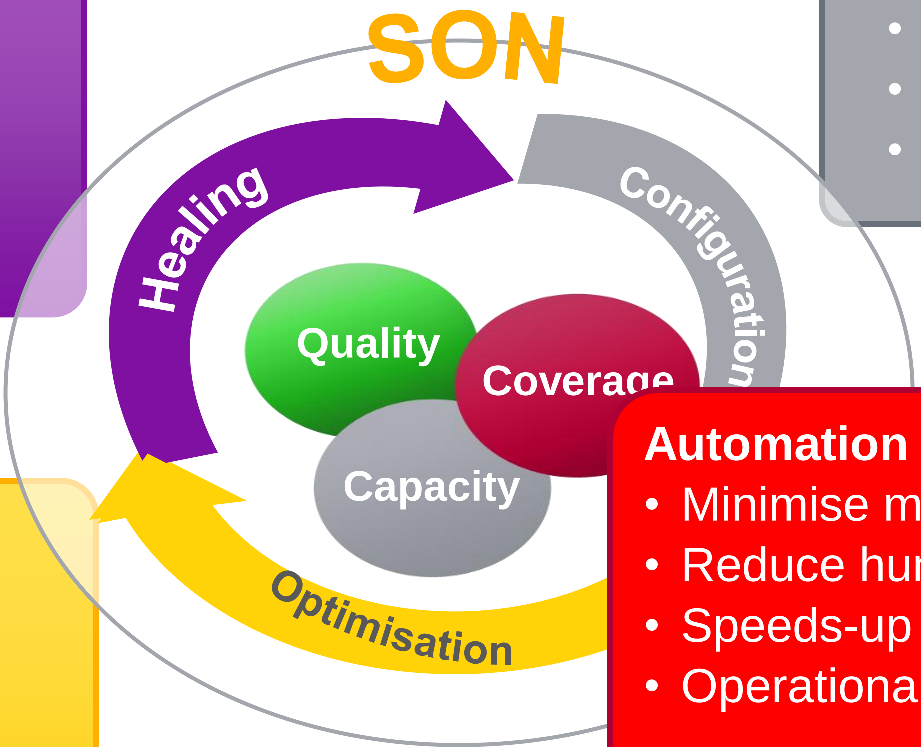
- Group of leading CSP’s indentified and specified in 2006 NGMN forum the Self Organising Networks as an important, new solution to meet the challenges of
  - data traffic growth
  - declining voice ARPU
  - investments to new technologies and network expansions
- SON is today 3GPP standardised for LTE
- Standardisation defines concept, interfaces and measurements for SON leaving e.g. implementation methods open.
- SON key objectives
  - Reduce complexity and cost of network operations
  - Maintain and improve quality of the networks
  - Cost effective introduction of new technologies
  - Protect network investments

Self-Organizing Networks
Intelligent Automation e2e



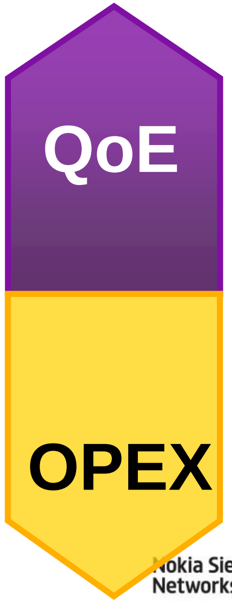
Self-Healing
- Error detection
- Error mitigation
- Alarm Mgt.
- Root cause analysis

Self-Configuration
- Site Creation
- Connection
- Configuration
- Neighbours



Self-Optimization
- Interference
- Mobility
- Load/Capacity
- Measurement Collection
- Energy

Automation
- Minimise manual tasks
- Reduce human errors
- Speeds-up operations
- Operational efficiency



SON- some important use cases

- Configuration of Physical Cell ID (*self configuration*)
- Automatic Neighbor Relations (ANR) (*self configuration*)
- Mobility Load Balancing (MLB) (*self optimization*)
- Mobility Robustness Optimization (MRO) (*self optimization*)
- Energy Saving (*self optimization*)
- Minimization of Drive Test (MDT)

SON framework in 3GPP

MOBILE BROADBAND
SON

- Release 8 functionality
  - Self-configuration procedures
- Release 9 enhancements
  - Self-optimization procedures
  - LTE Energy Saving Intra-RAT
- Release 10 objectives
  - Extend Self-optimization procedures , including inter-RAT
  - Minimization of Drive Test (MDT)
  - Energy Saving extension, including Multi-RAT (Study Item)
  - 3G-ANR
  - SON Conflict Resolution
- Release 11 proposals on hold until in June 2011 (RAN#52)
  - LTE SON extensions
  - MDT enhancements
  - HSDPA SON

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Use Cases in 3GPP

MOBILE BROADBAND
SON

RAN	Use case	Features	SA 5
	SON Conflict Resolution		Rel.10
	Self-healing	• Cell Outage Compensation	Rel.10
Rel.10	Self-optimization extensions	• Mobility Robustness Optimization • Mobility Load Balancing • Coverage and Capacity Optimization • 3G ANR	Rel.10
Rel.9	Self-optimization	• Mobility Robustness Optimization • Mobility Load Balancing • Energy Saving • RACH Optimization	Rel.9 (Mobility Robustness Optimization, Mobility Load Balancing) Rel.10 (Energy Saving, RACH Optimization)
Rel.8	Self-configuration	• SON Plug and Play • Automated Neighbor Relations Management (also Self-Opt) • Automatic SW Mgmt and Automatic Radio Configuration (R9)	Rel.8
Rel.10	Minimization of Drive Tests		Rel.10

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Agenda

Introduction

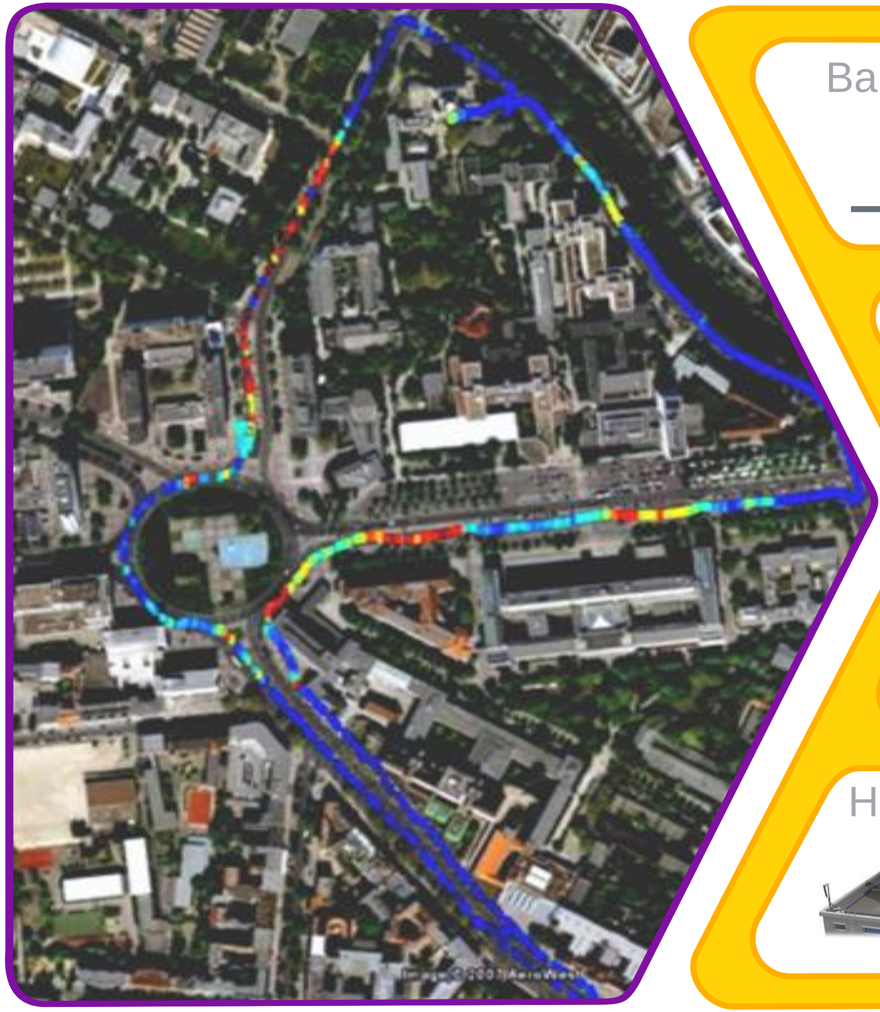
WCDMA/HSPA/HSPA+

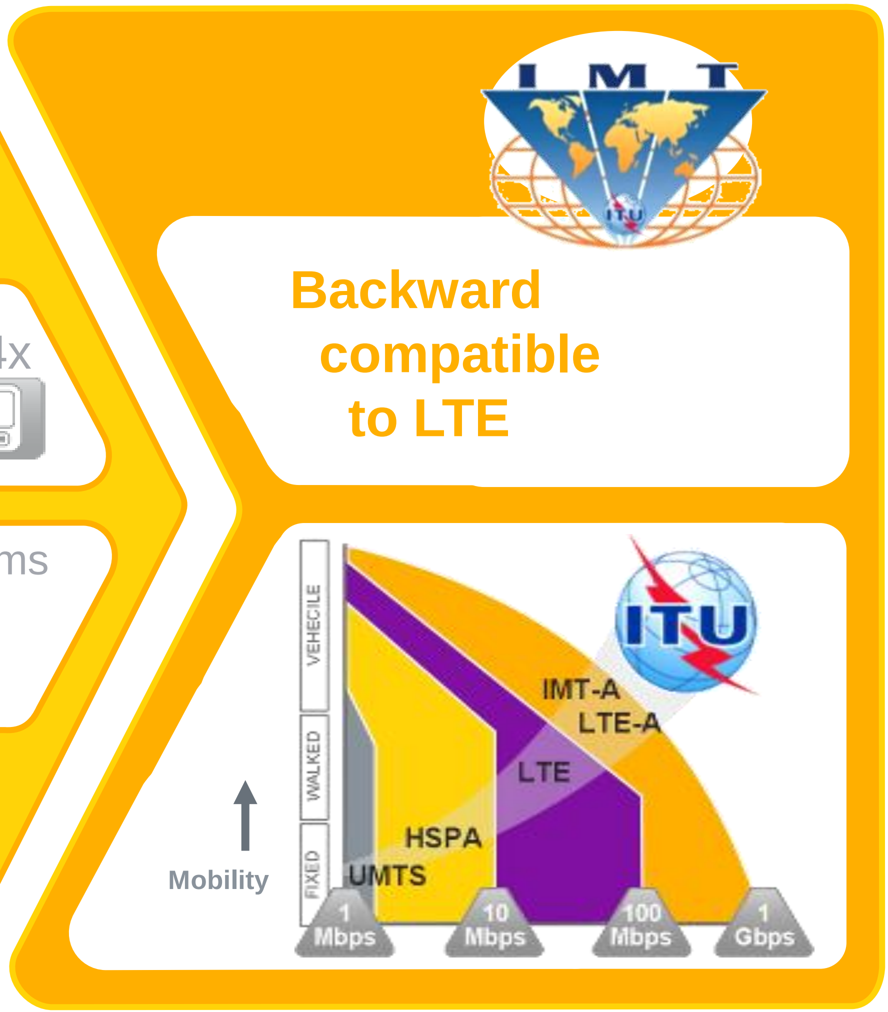
LTE

LTE-Advanced

Summary

LTE-Advanced Pushes Data Rates Beyond 1 Gbps





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Why do we now talk about LTE-Advanced?

- ITU-R has issued a Circular Letter early 2008 to invite candidate Radio Interface Technologies (RIT) for IMT-Advanced
- ITU-R requires “enhanced peak data rates” for IMT-Advanced:
  - 100 Mbit/s for high mobility
  - 1 Gbit/s for low mobility
- World Radio Conference (WRC-07) took decisions on Frequency Band identifications in November 2007 impacting IMT-2000 and IMT-Advanced
- In March 2008 3GPP has started a new Study Item on LTE-Advanced to enhance LTE to fulfill all IMT-Advanced requirements and to become IMT-Advanced candidate
- Currently, 3GPP RAN is studying and evaluating the performance of the new relevant technology components.

LTE-Advanced – Requirements and expectations:

Performance improvement and Backward Compatibility

- Meet and exceed capabilities requested for IMT-Advanced
- Meet 3GPP operators' requirements for LTE evolution
- Backward compatibility:
  - Release 8 UEs work in LTE-Advanced network
  - LTE-Advanced UEs work in Release 8 network
- Flexible and optimized spectrum usage
- Enable heterogeneous networks incl. Relays, HeNBs, etc.
- Bandwidth extension up to 100 MHz

- Enhanced performance
  - Peak data rates of 1 Gbps DL and 500 Mbps UL
  - 50% higher average cell spectral efficiency than LTE Release 8

LTE-A provides a toolbox of solutions improving radio performance:

	Peak rate	Average rate (capacity)	Cell edge rate (interference)	Coverage (noise limited)
Carrier aggregation	++	+	++	+
MIMO enhancements[1]	++ (o)	++ (+)	++ (+)	o
CoMP[2]	o	+	+	++
Heterogeneous networks	o	++	++	+
Relays	o	o	+	++

= clear gain (green) = moderate gain (purple)

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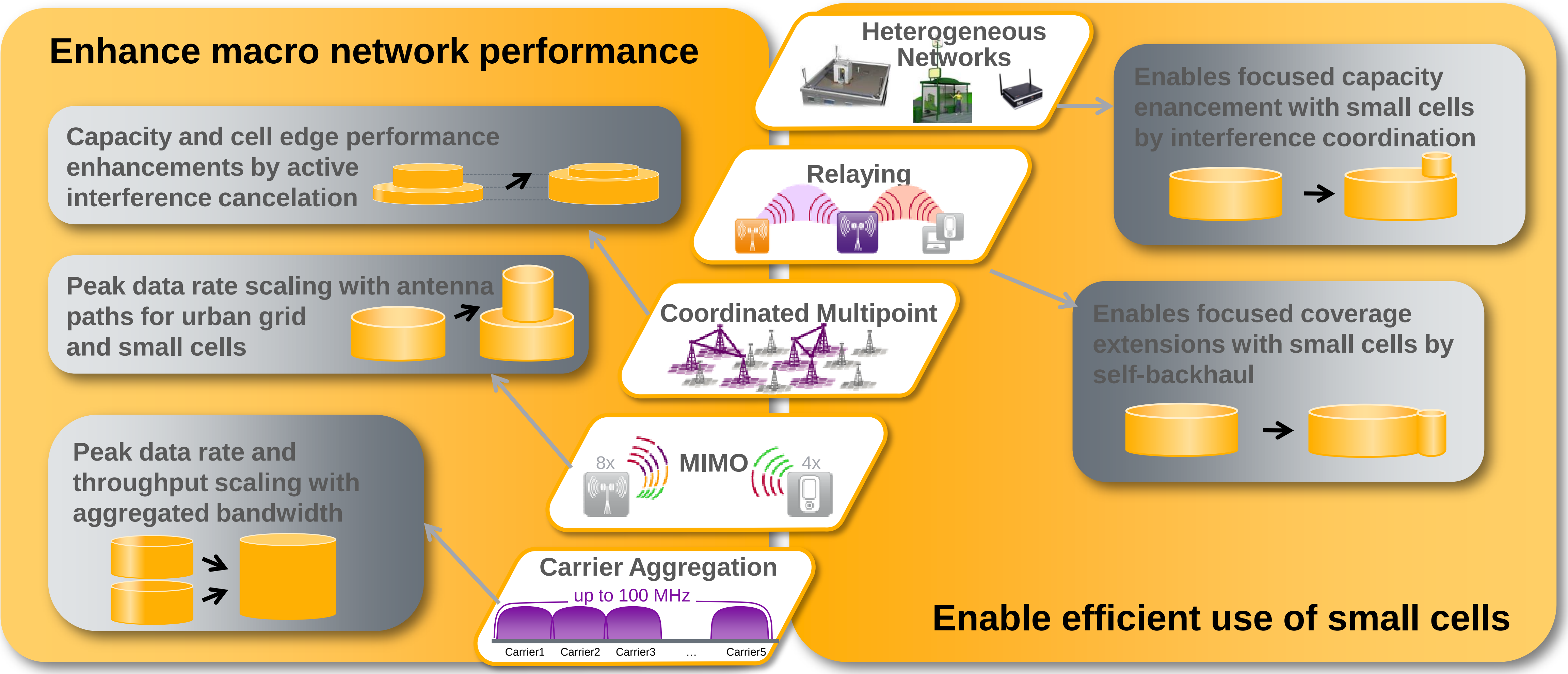
The LTE-Advanced toolbox for delivering more data efficiently to wide areas and hotspots



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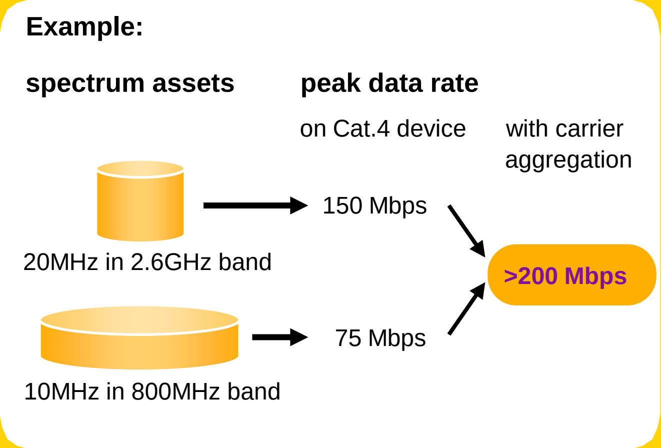
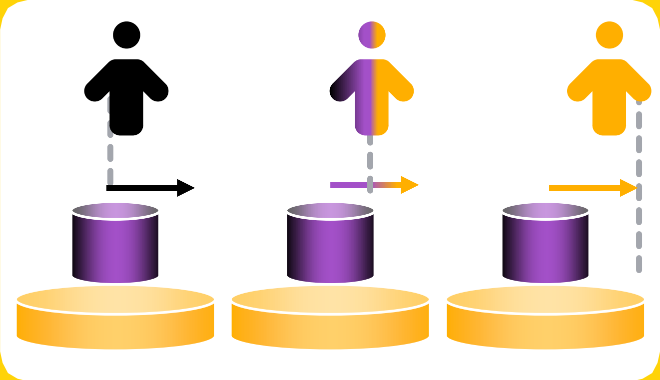
LTE-Advanced: Carrier aggregation
More dynamic spectrum usage for better user experience

Peak data rate addition



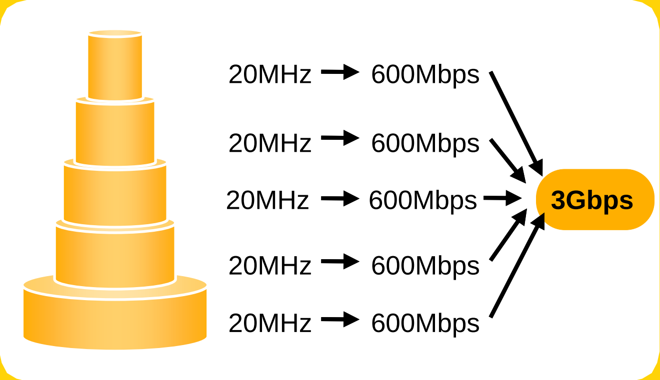
- enables **competitive peak data rates** on non-contiguous spectrum
- Mitigates the challenge of fragmented spectrum

Resource allocation gain



- Ultrafast resource allocation by scheduler instead of handover
- Users dynamically get the best resources of aggregated carrier
- **Higher average data rates**

3 Gbps



- Will be specified in **3GPP Rel.11 or later**
- Most operators have significantly less spectrum for LTE
- Even HD streaming services demand less than 20Mbps

Relevant scenarios under standardisation (3GPP Rel.10/11)

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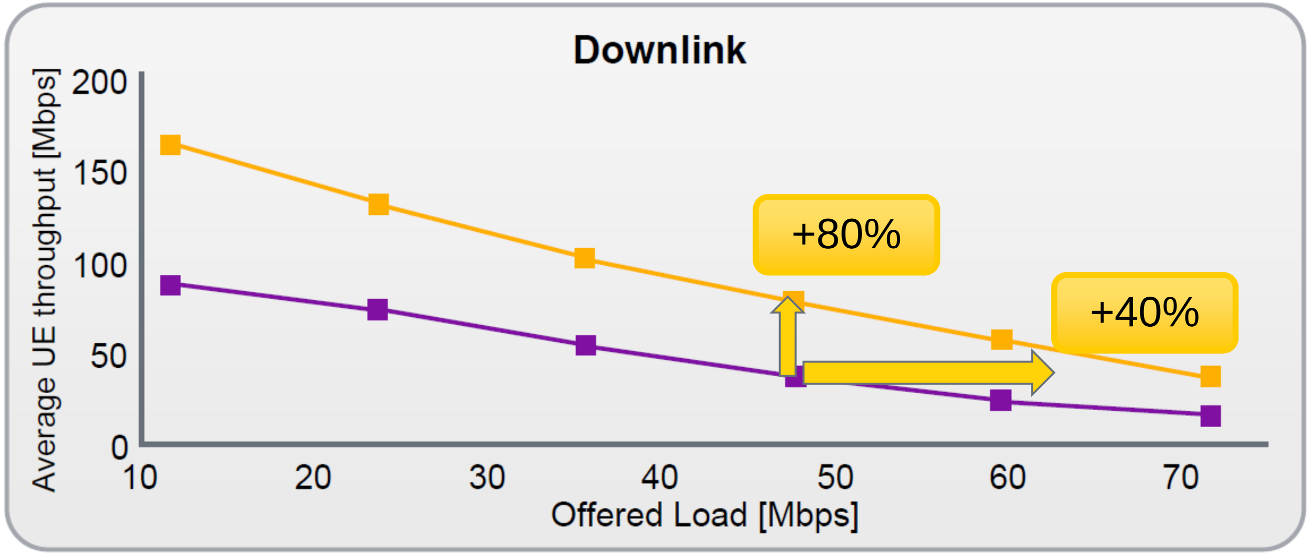
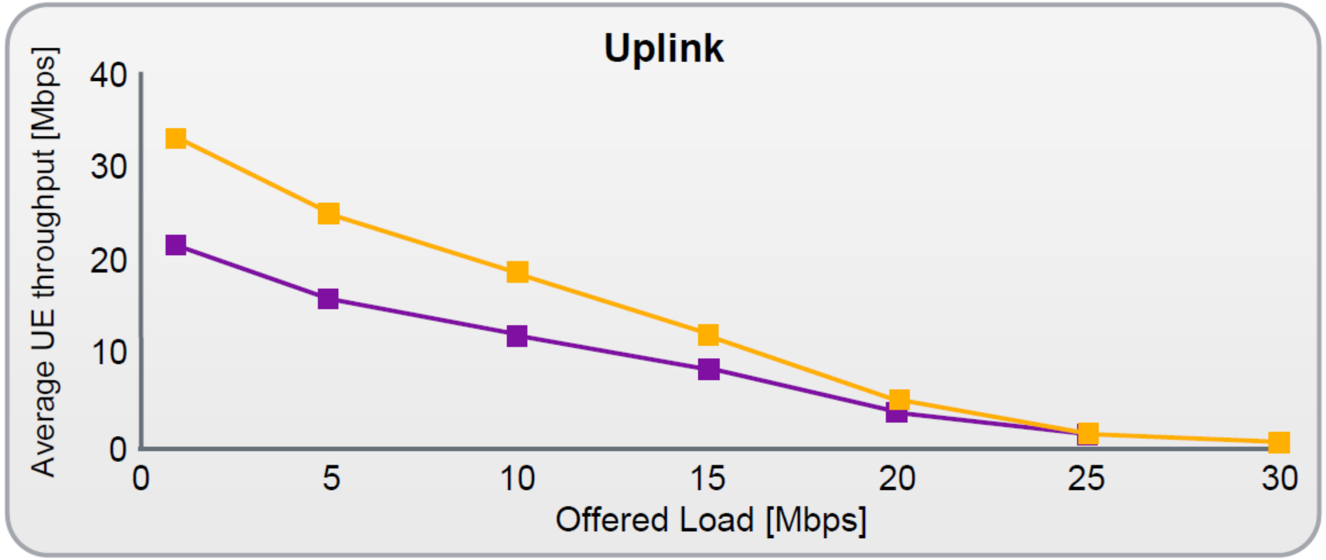
Carrier Aggregation Push Practical Data Rates and Efficiency





- +80% higher user data rate or +40% more capacity with carrier aggregation in downlink
- The reference case with Releae 8 is without carrier aggregation but with load balancing
- Dynamic traffic profile with Poisson arrival process and finite buffer

= Release 10 with carrier aggregation 20 MHz + 20 MHz

= Release 8 with two separate 20 MHz + 20 MHz

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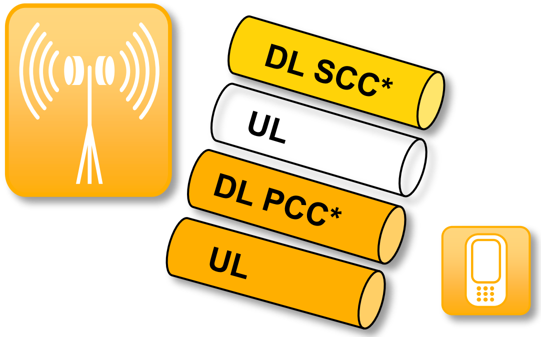
LTE-Advanced: Carrier aggregation Initial focus on Downlink

- Downlink carrier aggregation for 2 component carriers
- Up to 40 MHz combined bandwidth
  - Inter-band
  - Intra-band contiguous allocation
- PCC* based mobility
- 3GPP defined band combinations



*Primary component carrier:
(from 3GPP Rel.8) -> mobility, data

*Secondary component carrier:
where available -> add-on data speed

Carrier aggregation bands in 3GPP rel 10 (Source: TS36.104, version 10.4.0)

Intra-band CA:

CA Band	E-UTRA operating band
CA_1	1 (generic example)
CA_40	40 (generic example)

Inter-band CA:

CA Band	E-UTRA operating bands
CA_1-5	1 + 5 (generic, Korea)

CA band WI (planned for Dec. 2012)

Inter-band CA:

CA Band	E-UTRA operating band
CA_3-7	3 + 7 (TeliaSonera)
CA_4-13	4 + 13 (Verizon)
CA_4-17	4 + 17 (AT&T)
CA_20-7	20 + 7 (Orange etc.)
CA_5-12	5 + 12 (US Cellular)
CA_4-12	4 + 12 (Cox)
CA_2-17	2 + 17 (AT&T)
CA_4-5	4 + 5 (AT&T)
CA_5-17	5 + 17 (AT&T)
CA_1-7	1 + 7 (China Telecom)
CA_3-5	3 + 5 (SK Telecom)
CA_4-7	4 + 7 (Rogers)
CA_20-3	20 + 3 (Vodafone)
CA_20-8	20 + 8 (Vodafone)

Intra-band CA:

CA Band	E-UTRA operating band
CA_41	41 (Clearwire, CMCC)
CA_38	38 (CMCC)
CA_7	7 (CUC,CTC,Telenor, etc.)
CA_25	25 (Sprint;target June 2013)

LTE FDD

Band	MHz	Uplink MHz	Downlink MHz	
1	**2x60**	**1920-1980**	**2110-2170**	**UMTS core**
2	**2x60**	**1850-1910**	**1930-1990**	**US PCS**
3	**2x75**	**1710-1785**	**1805-1880**	**GSM 1800**
4	**2x45**	**1710-1755**	**2110-2155**	**NAM AWS**
5	**2x25**	**824-849**	**869-894**	**850**
7	**2x70**	**2500-2570**	**2620-2690**	**2600 FDD**
8	2x35	880-915	925-960	GSM 900
9	2x35	1749-1784	1844-1879	Japan, Korea 1700
10	2x60	1710-1770	2110-2170	US AWS extension.
11	2x20	1427.9-1447.9	1475.9-1495.9	Japan 1500
12	2x18	698-716	728-746	US
13	**2x10**	**777-787**	**746-756**	**Verizon**
14	2x10	788-798	758-768	US – Public Safety
17	**2x12**	**704-716**	**734-746**	**AT&T**
18	2x15	815-830	860-875	Japan – 800 (KDDI)
19	2x15	830-845	875-890	Japan – 800 (DoCoMo)
20	**2x30**	**832-862**	**791-821**	**EU 800 DD, MEA**
21	2x15	1448-1463	1496-1511	Japan 1500
22	2x80	3410-3490	3510-3590	3.5 GHz FDD (band 42–FDD variant)
23	2x20	2000-2020	2180-2200	US S-band
24	**2x34**	**1626.5-1660.5**	**1525-1559**	**US (LightSquared)**
25	2x65	1850-1915	1930-1995	US PCS extension (Sprint)
26	2x35	814-849	859-894	850 extension (Korea-KT, Sprint)

TD-LTE

Band	MHz	Uplink MHz	Downlink MHz	
33	1x20	1900-1920	1900-1920	UMTS core – TDD
34	1x15	2010-2025	2010-2025	UMTS core – TDD, China TD/SCDMA
35	1x60	1850-1910	1850-1910	US (band 2 – TDD variant)
36	1x60	1930-1990	1930-1990	US (band 2 – TDD variant)
37	1x20	1910-1930	1910-1930	US PCS centre-gap
38	**1x50**	**2570-2620**	**2570-2620**	**China, LatAM, Europe**
39	1x40	1880-1920	1880-1920	China PHS
40	**1x100**	**2300-2400**	**2300-2400**	**MEA, India, China, Russia**
41	1x194	2496-2690	2496-2690	US (Clearwire)
42	1x200	3400-3600	3400-3600	3.4/5 GHz – TDD
43	1x200	3600-3800	3600-3800	3.7/8 GHz – TDD

Source: TS 36.101; ***commercialized bands***

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Band Combinations

- Downlink carrier aggregation for 2 component carriers
- Up to 40 MHz combined bandwidth
- 36 combinations in total
- 13 combinations for North America
- 8 combinations for Japan
- 5 combinations for Korea
- Part of Release 11 combinations still under work
- Release 12 combinations planned for next year
- No FDD + TDD aggregation

	Release 10		Release 11		Release 12	
Inter-band	1 5	Korea	3 7	Teliasonera	3 5	SK Telecom
			4 13	Verizon	2 4	TMO USA
			4 17	AT&T	23 x	Dish
			7 20	Orange etal	3 26	KT
			5 12	US Cellular	3 28	eAccess
			4 12	Cox	3 19	Docomo
			2 17	AT&T	38 39	CMCC
			4 5	AT&T	1 8	Softbank
			5 17	AT&T		
			1 7	China Telecom		
			3 5	SK Telecom		
			4 7	Rogers		
			3 20	Vodafone		
			8 20	Vodafone		
			1 18	KDDI		
			1 21	Docomo		
			11 18	KDDI		
			3 8	KT		
Intra-band	1	Generic	41	Clearwire, CMCC	3	SK Telecom
	40	Generic	38	CMCC	4	TMO USA
			7	CUC, CT, Telenor	25	Sprint
					1	KDDI

1800 + 2600 (3 7 Teliasonera)

800 + 2600 (7 20 Orange etal)

800 + 1800 (3 20 Vodafone)

800 + 900 (8 20 Vodafone)

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Evolution of LTE User Equipment categories to LTE-A

All commercial LTE devices in the market 2011/2012 (Class 3)

Some devices launched in late 2012 (Class 4)

LTE-Advanced devices will be based on these User Equipment categories (Class 6, Class 7, Class 8)

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
Peakrate DL/UL	10/5 Mbps	50/25 Mbps	100/50 Mbps	150/50 Mbps	300/75 Mbps	300/50 Mbps	300/100 Mbps	3000/1500Mbps
RF Bandwidth	20 MHz	20 MHz	20 MHz	20 MHz	20 MHz	40 MHz	40 MHz	100 MHz
Modulation DL	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM
Modulation UL	16 QAM	16 QAM	16 QAM	16 QAM	64 QAM	16 QAM	16 QAM	64 QAM
MIMO DL	optional	2 x 2	2 x 2	2 x 2	4 x 4	2x2(CA) or 4x4	2x2(CA) or 4x4	8 x 8
MIMO UL	no	no	no	no	no	no	2 x 2	4 x 4

Defined in initial LTE release (3GPP Release 8) (Class 1–5)

Defined in initial LTE-A release (3GPP Rel. 10) (Class 6–8)

Carrier aggregation of 40MHz (Class 6–7)

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Overview - Mobile Broadband Downlink peak data rate evolution

LTE ➔ **LTE-Advanced**

100 Mbps (Cat.3 devices)
150 Mbps (Cat.4 not yet available)
20 MHz
2x2 MIMO (4x4 MIMO not optimized)

300 Mbps
(Cat. 6, 7 devices)
40 MHz
2x2 / 4x4 MIMO

3Gbps
(Cat. 8 devices)
100 MHz
8x8 MIMO

HSPA+ ➔ **Long Term HSPA Evolution**

21 Mbps
5 MHz
No MIMO

42 Mbps
10 MHz
No MIMO

84 Mbps
10 MHz
2x2 MIMO

168 Mbps
20 MHz
2x2 MIMO

336-672 Mbps
40 MHz
2x2 / 4x4 MIMO

Release 7 | **Release 8** | **Release 9** | **Release 10** | **Release 11 and beyond** | **3GPP timeline**

Nokia Siemens Networks

Agenda

MOBILE
BROADBAND

- Introduction
- WCDMA/HSPA/HSPA+
- LTE
- LTE-Advanced
- **Summary**

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Networks

Summary (1/3)

WCDMA/HSPA/HSPA+

- Strong momentum and growth in Mobile Broadband with terminals, network technology and applications
- WCDMA has both FDD (widely used) and TDD variant with FDD using 5+5 MHz and TDD 5 MHz as single carrier
- HSPA/HSPA+ is a mature technology with broad ecosystem support, which will further evolve and will remain dominant technology for many years to come
- Carrier aggregation and MIMO pushes the peak data rates and cell throughput

Summary (2/3)

LTE

- Motivation of LTE is need for higher peak data rate, spectral efficiency, less round trip delay, packet optimized network, high degree of mobility and spectrum flexibility
- LTE has both FDD and TDD variant with frequency allocation flexibility with 1.4, 3, 5, 10, 15 and 20 MHz spectrum
- LTE frequency bands for Europe are 2600 (capacity), 1800 (capacity) and 800 (coverage) MHz
- LTE uses OFDMA in DL and SC-FDMA UL for multiple access technology. OFDMA in DL minimizes receiver complexity while SC-FDMA improves battery life time in receiver
- LTE is packet oriented flat network with minimum no. of nodes- only eNodeB in access and MME, SAE-GW (S-GW/P-GW) in core networks. (additionally, HLR/HSS, PCRF and IMS is required in core)
- Voice in LTE is accomplished by CS Fallback (initially) and SR-VCC (later).

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Summary (3/3)

SON

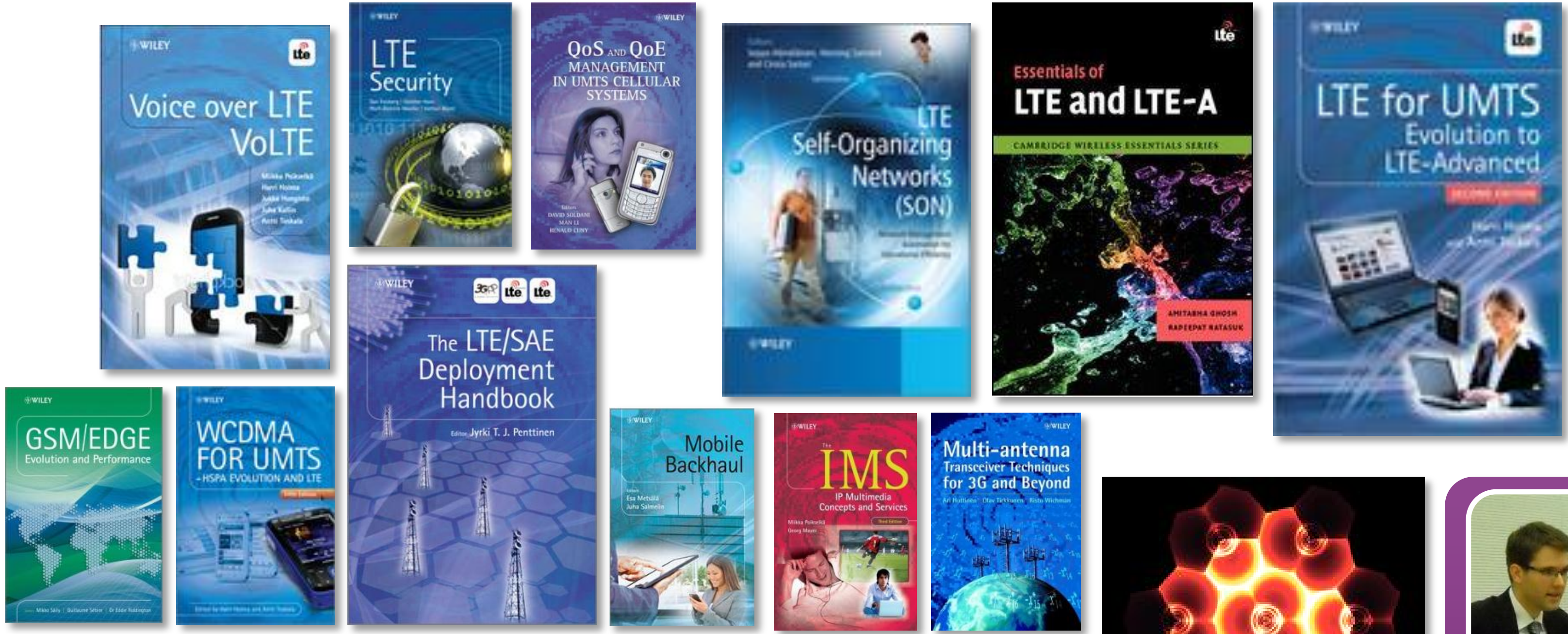
- SON is a set of network algorithms for simplifying network configuration, optimization and healing
- SON algorithms can be centralized targeting multi-cell optimization or distributed for fast and local optimization or a hybrid (combination of all)
- SON is not limited to LTE only but many of these SON algorithms are applied to 3G/HSPA networks as well

LTE-Advanced

- LTE-A in Rel-10 adds several enhancements in LTE
- Improvements in peak and average data rates using carrier aggregation, increased number of antennas and advanced antenna technologies
- Further improvements by use of relay and interference management
- LTE-A with Rel-10 fulfills and exceeds requirements for IMT-Advanced
- LTE-A can achieve peak data rates as high as 3 Gbps in DL and 1.5 Gbps in UL direction with 100 MHz spectrum

Nokia Siemens Networks

Nokia Siemens Networks LTE R&D
Research and publications bringing the industry forward

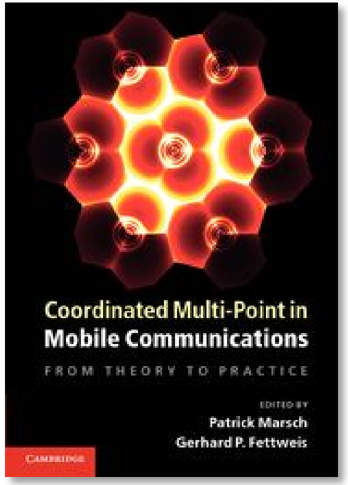


Antti Toskala

LTE Award for individual contribution to LTE development

More than 130 published LTE research papers in 2010 and 2011

- LTE-Advanced, SON, heterogeneous networks,…
- Published/accepted research conference articles and journal papers (IEEE, VTC,….)



Patrick Marsch

Johann Philipp Reis Prize 2011

for his pioneering research on Coordinated Multi-Point

